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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. X. — *On the Mechanical Equivalent of the Heat Vaporization of Water;* by R. H. HOUGH.

THE object of this investigation is the development of a method for the determination of the mechanical equivalent of the heat of vaporization of water directly in ergs: i. e., of a method not involving the use of the calorie.

This equivalent, which will be designated in what follows by L, is usually expressed in terms of the calorie varying from 536 C. to 540 C., depending on the particular calorie taken as the unit and the particular method pursued.

Regnault's is the only classic determination. He defined the calorie as the amount of heat to raise a kilogram of water from 0° to 1°, and worked out the following formula:

$$L=606{\cdot}5-0{\cdot}695t-0{\cdot}00002t^2-0{\cdot}0000003t^3$$

At standard pressure this gives the value 536·5, which is generally used by physicists, notably by Joly in the reduction of his determinations with the steam calorimeter. In close agreement with this value is the 536·2 of Berthelot, whose method was much less complicated. The empirical formula of Griffith:*

$$L=596{\cdot}73-0{\cdot}601t$$

gives the value 536·63 in terms of the calorie from 14°·5 to 15°·5 centigrade. This agreement is only apparent, and a more just value of L is obtained by following Callendar,† who estimated L from the observations of Joly and Barnes. Joly‡

* Griffith, Phil. Trans. A., 1895, p. 261.
† Callendar, Proc. Roy. Soc., lxvii, 1900.
‡ Joly, Proc. Roy. Soc., xlvii, 1889.

determined the mean specific heat of water from 12° to 100° in terms of the calorie at 20° using the following relation:

$$w\mathrm{L} = \mathrm{W}s(t_1 - t_2)$$

observing w, W, t_1, and t_2, and taking Regnault's value of L, 536·5. Callendar substitutes in this relation Joly's observations of w, W, t_1, and t_2, and Barnes'* determination of the mean specific heat of water from 12° to 100° in terms of the calorie at 20° and solves for L. This gives the value of 540·2 in terms of the calorie at 20°. Callendar prefers this value to that of Regnault and uses it in his work on the properties of steam. It is probable that even this value is low, since Barnes'† values for the specific heats of water from 40° to 100° are almost parallel to but much lower than those of Regnault. There is much uncertainty as to the value of L in calories.

There is as yet no absolute determination of L in ergs. It may be expressed in ergs, however, as the product of L in calories into the mechanical equivalent of heat. Using 540·2 as the most probable value of L in calories at 20° and $4{\cdot}184\times10^7$ as the most probable value of the mechanical equivalent at 20°, this being an average of the values due to Barnes, Rowland, Griffith, Schuster, and Moorby, gives $2{\cdot}26\times10^{10}$ against $2{\cdot}24\times10^{10}$ from Regnault's value.

The sources of error for this value are many. It can not be stated that the mechanical equivalent of the heat of vaporization of water is known with certainty to one per cent.

In any method of calorimetry involving the use of the calorie, no greater degree of accuracy can be attained than that of the calorie itself. But the determination of the value of C involves the use of the thermometer and all the errors incident to the measurement of temperature. That these are greater and more varied than is commonly supposed, and can only be corrected for by the exercise of the greatest care and skill, is definitely shown by Rowland‡ in his work on thermometry. He sees visions of careful, painstaking observers conscientiously reading with telescope and micrometer eye-piece to the thousandth part of a degree, unconscious of the fact that variations due to internal and external pressure, apparent friction and previous history, to say nothing of those due to the sectional calibration and the fundamental points, are many times as great as the usual errors of parallax and estimation.

Griffith,§ who is not so caustic though quite as vigorous, says: "The difficulties with regard to the measurement of temperature are not peculiar to the electrical method of inves-

* Brit. Assoc. Rep., 1889. † Phil. Trans. A., 1902, vol. cxcvii.
‡ Rowland, Proc. Am. Acad. of Arts and Sciences, vol. xv.
§ Griffith, Phil. Trans., 1893.

tigation, and therefore I need not dwell upon them. I would, however, venture to add my expressions of astonishment to those of Rowland, that so many enquirers attach so little importance to this point: many investigators, whose methods have otherwise been of a high order of accuracy, having satisfied themselves with the mercurial thermometer as a standard." Rowland* rejects, as having no weight, previous determinations in which the thermometer readings were not reduced to the air scale. As to the difficulty of this reduction, and to the general uncertainty of the apparent readings of the ordinary thermometer, a very instructive object lesson is to be found in an article by Cole and Durgan,† entitled "An Example in Thermometry."

It is the record of a systematic calibration of a Gerhardt thermometer, made in a concise and thorough manner. The mere statement of the corrections made, the record of the observations, and the results of the calculations, stated as briefly as consistency with clearness would permit, occupy twenty pages. In his determination of the mechanical equivalent of heat, Rowland made the most involved and elaborate corrections on his thermometer readings, and only brought his results and those of Joule into agreement by making the same kind of corrections for the latter's thermometers. Without raising the question of the soundness of such corrections, it is evident that a method for the determination of any fundamental heat constant independent of them is desirable if only to serve as a check: for the only way to minimize their effect is to extend the range of temperature, which is sure to increase the errors due to radiation, conduction and the calorimeter constant.

The error due to the latter constant need not be large, provided only that the water equivalent of the calorimeter be small compared with that of the substance under observation, and this can usually be accomplished without much difficulty.

The error due to the water vapor in the steam is only present in methods of steam calorimetry and is almost entirely eliminated by the differential method.

The errors due to radiation, convection and conduction are more serious. Reynolds‡ remarks on Joule's determination "that notwithstanding the greater facilities enjoyed by subsequent observers owing to the progress of physical appliances, the inherent difficulties remained: the losses from conduction and radiation could only be minimized by restricting the range of temperature and this ensured thermometric difficulties, par-

* Rowland, Proc. Am. Acad., vol. xv.
† Cole and Durgan, Phys. Review, vol. iv, 1896.
‡ Reynolds, Phil. Mag., 1897.

ticularly with the air thermometer which does not admit of very close reading." In fact, so uncertain are the corrections for radiation and conduction, that Griffith* asserts as "the general principle on which he proposed to work, that of eliminating the effects of radiation, conduction, etc., rather than that of ascertaining the actual loss or gain due to such causes." He eliminates these effects by maintaining the walls of the chamber enclosing his calorimeter at a constant temperature and gradually raising the temperature of the calorimeter from some point below to some point above that of the jacket, such that the gain and loss by the calorimeter are equal. This he calls the null point and determines it experimentally. The correction for convection by this method is doubtful. Rowland, who also bunches the losses due to radiation, convection and conduction, estimates the loss by convection to be more than 75 per cent of the total losses from these causes. He likewise corrects empirically. Obviously a better plan would be to eliminate not only the effects but the cause of these errors by maintaining the calorimeter, the jacket and the intervening medium at the same constant temperature, if a method admitting of such a process is possible. In fact, the principle of elimination of source of error is fundamental to all physical measurements since minimization and correction formulæ can never be more than a series of successive approximations.

The grounds then for a new method of determining L are: (*a*) the absence of any authoritative determination; (*b*) the absence of any absolute method; (*c*) the inherent sources of error in the present indirect methods. These are sufficient but there are weightier considerations: i. e. the advantages resulting from the use of L as the primary heat unit. Much can be said in favor of L instead of C as the primary heat unit, especially since the development of steam calorimetry by Bunsen and Joly.

The substance under calorimetric observation may be in a thermo-dynamic or in a thermo-static condition. The temperature may be changing, or it may be constant. In the first case the thermometer should be accurate, delicate and sensitive. That is to say, that not only should all corrections to reduce its readings to the air scale be definitely known, but it should respond to small variations of temperature in a readable degree and respond quickly. In this case the readings must be taken rapidly and are necessarily limited in number. In the second case the thermometer should be accurate and delicate but not necessarily sensitive to a higher degree. The readings may be taken more leisurely, with greater precision, and are only

* Griffith, Phil. Trans., 1893.

limited in number by expediency. It is apparent that methods necessitating observations of the first class are, other things being equal, inferior to those involving readings of the second class only. The determinations of Regnault, Joule, Rowland, Moorby, Griffith and Barnes all involve observations of the first class. In Joly's method of steam calorimetry, however, the temperature readings are made while the substance is in a state of thermal equilibrium which may be maintained almost indefinitely.* In this respect his method is unsurpassed. An absolute determination of L substituted for the Regnault value used by Joly would enhance the value of his work many fold. His differential method is unquestionably the best general method of calorimetry yet devised, the use of an uncertain constant being, as Joly himself pointed out, its weakest point.

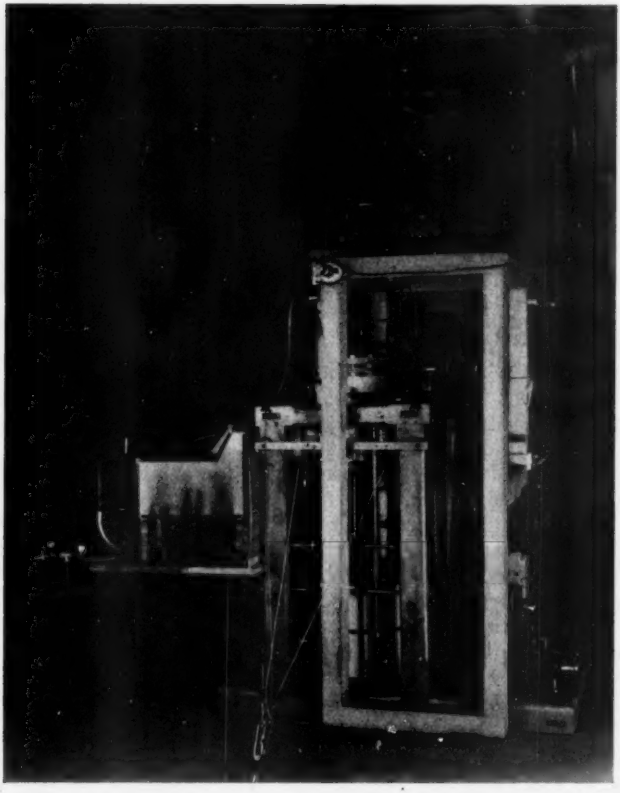
Barnes' curve for the heat capacity of water from 0° to 100° will never be changed much except, perhaps, by shifting the origin along the axis of specific heats. Rowland determined only a small portion of this curve, which from 10° to 20° is practically parallel to Barnes' but lower in value. Regnault determined the portion of the curve between 40° and 100°. It is also practically parallel to Barnes' but much higher. This indicates the presence of constant errors—but where? In this particular work the men are to be given almost equal weight. A constant error in Rowland's work, whose results agree among themselves most perfectly but for which he only claims an accuracy of two parts in a thousand, is hard to locate. It is possibly due to the sensitiveness of his thermometers not being great enough for observations on a substance in a thermodynamic condition. Regnault's constant error is likely due to several causes, including radiation, while Barnes' is possibly due to the position of his thermometers, as this is a source of error common to all continuous methods and very hard to eliminate or to correct for. In some preliminary work on the ratio of L to C, an attempt was made to develop a continuous method of steam calorimetry. It was abandoned for a time at least because the results, while agreeing very well among themselves, were found to be a function of the position of the thermometers placed in the ingoing and outcoming water. It would not be safe then to decide which of these curves, agreeing so well in all but their positions, is nearest to the true one. The substitution of the true value of the heat of vaporization of water in Joly's determination of the mean specific heat of water from 12° to 100° in terms of the calorie at 20°, would give a value by which Barnes' curve could be shifted. In this way much of the work of previous investigators in calorimetry

* Joly, Proc. Roy. Soc., vol. xlvii, 1889.

would be enhanced in value. Hence an absolute determination of the mechanical equivalent of the heat of vaporization of water is a thing to be desired in itself.

The present method aims at the elimination of the errors due to thermometry, the calorimeter constant, the water vapor in the steam, radiation and convection, and a rigorous correc-

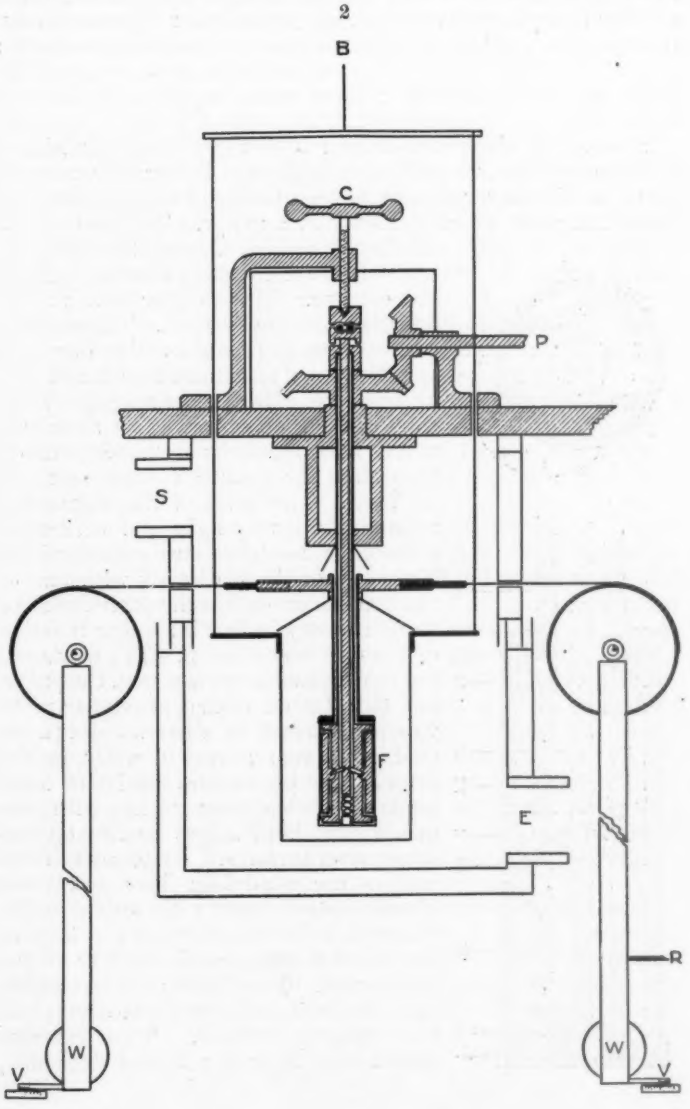
1



tion for conduction. The devices used to attain these ends will be described in detail followed by a discussion of the principles involved.

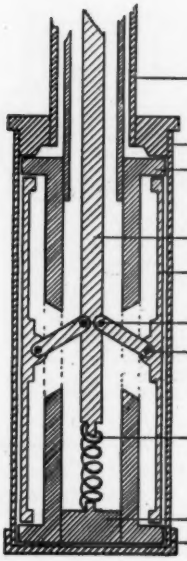
The general plan of the machine and the relation of its parts is best shown by the photograph (fig. 1) and the conventional diagrams (figs. 2 and 3). It consists essentially of (*a*) a vertical

shaft to which power is supplied: (*b*) a friction brake of peculiar design to convert the mechanical energy into heat: (*c*) a controlling device to maintain a convenient constant load: (*d*)



a cup suspended from the arm of a balance to hold the water to be evaporated: (*e*) two bent levers to balance the friction against gravity: (*f*) a recording device to plot the variation of the mechanical force with the number of revolutions: (*g*) a counter to register the number of revolutions: (*h*) a clutch for throwing the recorder and the counter in or out of gear at will: (*i*) a double-walled jacket: (*j*) a shield between the cup and the jacket to prevent radiation: (*k*) a steam supply to furnish the steam bath.

The vertical shaft consists of a hollow steel tube turned and fitted to accurately bored brass boxings. Power is communicated to this through the bevel gearing at the top from the horizontal shaft which is driven by a motor. To this horizontal shaft is geared, through the clutch by which they are operated, the recorder and the counter. The counter is a Veeder and gives excellent service. The recorder consists simply of a horizontal drum whose angular velocity is a linear function of that of the brake. This carries the paper vertically under the marker. The marker is moved horizontally by means of the familiar device for parallel motion invented by Watt. The parts of this registering apparatus are very light and accurately centered on hardened steel cone bearings. They communicate directly with one of the bent levers so that the position of the marker at any instant is a linear function of the mechanical force. The marker is not in continuous contact with the paper, but only for an instant at regular intervals when struck by a bar which is actuated by a cam geared directly to the drum. The bent levers consist of accurately turned cast-iron pulleys with hardened steel knife edges bearing on hardened steel surfaces. Attached to these pulleys are pendulum bars and bobs. Flexible steel tapes with swivel joints transmit the moment from the disk of the friction brake to the pulleys of the bent levers. The friction brake consists of a bobbin threaded to the vertical shaft and rotating with it. Two rubbers, quadrant sections of a turned steel tube,



are hinged to the bobbin by means of a double joint which permits radial motion. A toggle joint, operated by a rod inside the vertical shaft, connects the two rubbers diametrically through an opening in the bobbin. This rod is forced upwards by means of a strong spiral spring in the bottom of the bobbin, and draws the rubbers in toward the center at the same time. When pressed down by the controlling device at the top, it forces the rubbers out radially. Surrounding the rubbers and accurately turned to fit them, is a cylinder supporting a torsion disk at the top. As the shaft rotates the rubbers move with it, and on account of the friction drag the cylinder and the torsion disk at the top with them. This motion is communicated by the tapes to the pulleys of the bent levers and the pendulums are displaced until their moment is equal to that of the friction. The double hinged joints are the important feature of this device. They permit the rubbers to seat themselves perfectly in the cylinder and the resulting friction is very uniform. In fact, the small periods of its variations are so short compared to that of the long bent levers that they are completely integrated by these levers, the record being almost a straight line. The controlling device consists of a hand screw to force down the rod operating the toggle joint. This pressure is transmitted through the ball-bearing since the rod is rotating with the shaft.

The manipulation of the machine is quite simple. A steam bath is allowed to flow through the chamber from the boilers throughout the experiment, maintaining all parts inside the shield at the temperature of the bath. The motor is started and the load is gradually increased by the control to the desired constant. When the water is evaporating freely and the thermal conditions have been maintained constant for some time, the weights are adjusted a little light and, as the water in the cup evaporates and the pointer comes to the zero, the clutch is operated throwing the counter and the recorder in gear, the weights and the counter having been observed and recorded. After any convenient period the weights are again adjusted a little light and the clutch again operated just as the pointer comes to zero, the counter and the weights being observed and recorded.

The calculation of the mass of the water evaporated is made in the usual way, but that of the mechanical energy may need a word of explanation. Since the ordinates and the abscissas of this curve are linear functions of the friction and the number of the revolutions of the rubbers, the following relations hold:

$$W = \int_0^s f.ds$$

$$= C\int_0^x y\,.\,dx$$
$$= C\,.\,A$$

but

$$A = X\bar{y}$$
$$= C_1 S\bar{y}$$

where $\bar{y}$ = average ordinate

$$S = n\,.\,2\pi r$$

where n = no. of revolutions
r = radius of disk

$$y = \frac{w_1}{w_2}\,l$$

where w_2 = total weight of paper
w_1 = weight of A
l = width of paper

$$c_1 = g\,.\,G$$

where g = acc. due to gravity
G = mass in grams to displace marker 1^{cm}.

$\therefore$

$$W = \frac{w_1}{w_2}\,l\,.\,g\,.\,G\,.\,n\,.\,2\pi r.$$

The constant G is determined by empirical calibration, for which four steps are necessary: the calibration of the scale of one of the pendulums in grams per centimeter by suspending weights in a pan from the pulley: the adjustment of the mass of the other pendulum bob to the same grams per centimeter: the adjustment of either tape until any deflection of the disk gives the same displacement on both scales: the calibration of the marker in terms of these scales. This determines G.

A second set of observations is taken using a second cylinder of different conductivity capacity from that of the first and L is determined from the following relation:

$$W = u_1 + u_2 + R$$

where u_1 = heat in ergs to the rubbers
u_2 = heat in ergs to water
R = heat in ergs radiated

if the temperature of the shield approaches that of the cylinder

$$R \doteq O \quad \text{and}$$

$$W \doteq u_1 + u_2$$

but $u_2 = (m + m')L$

where m = apparent loss of water in the cup
m' = water deposited on cup due to water vapor in steam

and if $m \doteq O$

$$u_2 = mL$$

$$W = u_1 + mL.$$

Let

$W = u_1 + u_2$ for the first cylinder
$W' = u'_1 + u'_2$ for the second cylinder
and $u_2 = m\,L$
$u'_2 = m'L$

$$\frac{u_1}{u'_1} = \frac{W - m\,L}{W' - m'L}.$$

But
$$du_1 = \frac{k_1 A_1}{l_1}(T_1 - T_2)dt$$
$$du_2 = \frac{k_2 A_2}{l_2}(T_1 - T_2)dt$$
$$du'_1 = \frac{k_1 A_1}{l_1}(T'_1 - T'_2)dt$$
$$du'_2 = \frac{k'_2 A'_2}{l'}(T'_1 - T'_2)dt$$

where k = specific conductivity
A = cross section of conductor
l = length of conductor
T = temperature
t = time

integrating

$$u_1 = \frac{k_1 A_1}{l_1}\int_0^t (T_1 - T_2)dt$$
$$u_2 = \frac{k_2 A_2}{l_2}\int_0^t (T_1 - T_2)dt$$
$$u'_1 = \frac{k_1 A_1}{l_2}\int_0^{t'} (T'_1 - T'_2)dt$$
$$u'_2 = \frac{k'_2 A'_2}{l'_2}\int_0^{t'} (T'_1 - T'_2)dt$$

and
$$\frac{u_1}{u'_1} = \frac{\int_0^t (T_1 - T_2)dt}{\int_0^{t'} (T'_1 - T'_2)dt}$$

$$\frac{u_2}{u'_2} = \frac{\frac{k_2 A_2}{l_2}}{\frac{k'_2 A'_2}{l'_2}} \cdot \frac{\int_0^t (T_1 - T_2)dt}{\int_0^{t'} (T'_1 - T'_2)dt}$$

$$= R \cdot \frac{\int_0^t (T_1 - T_2)dt}{\int_0^{t''} (T'_1 - T'_2)dt}$$

where R = ratio of the conductivity capacities of the two cylinders.

$$\frac{u_1}{u'_1} = \frac{u_2 I}{u'_2 R} = \frac{m I}{m' R}$$

$$\frac{m}{m'R} = \frac{W - mL}{W' - m'L}$$

$$L = \frac{W}{m} + \frac{1}{R-1}\left(\frac{W}{m} - \frac{W'}{m'}\right)$$

In the second term of the right hand member the two factors always have opposite signs. The correction is therefore a negative quantity. By reducing the conductivity capacity of the rubbers and increasing that of the cylinder, this correction is reduced to a minimum. Only the ratio of the conductivity capacities is demanded by this formula, not the specific conductivities. This ratio is determined by the method of cooling.

The advantages of this method are: the measurement of all quantities involved to a high degree of accuracy, depending only on the skill of the mechanician: the elimination of all errors due to thermometry, the calorimeter constant, the water vapor in the steam, radiation and convection: the minimization and rigorous correction for conduction.

Preliminary tests of the most rigorous type show that all the factors that enter into this result are entirely within control. A long series of observations are to be made during the coming year, from which it is confidently expected that a value accurate to at least one part in a thousand will be obtained.

University of Pennsylvania.

ART. XI.—*The Phosphorescence of Zinc Sulphide through the Influence of Condensed Gases obtained by Heating Rare-Earth Minerals;* by CHARLES BASKERVILLE and L. B. LOCKHART.

HELIUM has been shown to be a product of the disintegration of radium emanations; it is also obtained from minerals which contain thorium and uranium. It has been shown by Afanassiew, Mme. Curie, Crookes, Strutt, Hoffman, Baskerville, and Boltwood that minerals containing these elements are radio-active.

It seemed to be of interest to ignite these minerals and condense the gases given off and note their effect upon phosphorescent zinc sulphide. The method of procedure was essentially that described in the preceding paper, except that the pulverized mineral was placed in the closed tube of hard glass instead of a radium preparation. Screens of Sidot's blende were prepared in strips for the purpose. The glowing of the screen was assumed to indicate the condensation of the emanation.

No final conclusion could be drawn from the experiments, which were distinctly qualitative. It appeared, however, that those minerals which offer the richest sources of helium gave the greatest amount of emanation. Most of the minerals were obtained by purchase, but we are indebted to Dr. Geo. F. Kunz for some of them, to Dr. H. S. Miner, of the Welsbach Lighting Co., for others, and to the Nernst Lamp Co., Pittsburg, Pa., for still others.

In addition to the minerals we made some experiments with uranium compounds*, commercial thorium oxide, and the fractions of that element obtained in our laboratory.

The list of minerals, and observations follow:

Mineral.	Locality.	Result.
Aeschynite	Hitterö, Norway	Fair glow
Allanite (orthite)	Amherst Co., Virginia	No glow
Allanite	Amherst Co., Virginia	No glow
Annerödite	Norway	No glow
Auerlite	Henderson, N. C.	Fair glow
Bastnäsite	Manitou Springs, Col.	No glow
Brookite	Arkansas	No glow
Carnotite	La Salle Creek, Mont. Co., Colorado	Fine glow
Carnotite	Utah	No glow
Catapleiite	Brevig, Norway	No glow
Cerite	Bastnäs, Sweden	Fair glow
Cleveite	Moss, Norway	Fine glow
Columbite	Amelia Co., Virginia	No glow
Crytolite with Fergusonite	Bluffton, Texas (Llano)	Faint glow

*For which we are indebted to Dr. S. A. Tucker, Columbia University.

Mineral.	Locality.	Result.
Crytolite	S. Co., Texas	No glow
Euxenite	Spangercid, Norway	Fair glow
Euxenite	Arendal, Norway	Good glow
Fergusonite	Ytterby, Sweden	Fine glow
Gadolinite	Fahlun, Sweden	No glow
Gummite	Mitchell Co., N. C.	No glow
Hjelmite	Karapfvet	No glow
Monazite sand	Brazil, S. A.	Fair glow
Monazite	Norway	Medium
Monazite sand	Mitchell Co., N. C.	Very faint glow
Mixite	Joachimsthal, Bohemia	No glow
Orangite	Norway	Medium
Orthite	Arendal, Norway	No glow
Pitchblende (Uraninite)		Medium glow (below fair)
Pechurane	Bohemia	Strong glow
Samarskite	Mitchell Co., N. C.	Fine glow
Steenstrupine	Urals	No glow
Thorite	Langesund, Norway	Fair glow
Thorite (Orangite)	Brevig, Norway	Fair glow
Thorogummite	Bluffton, Llano Co., Tex.	No glow
Tritomite	Brevig, Norway	No glow
Tyrite	Tromsö, Norway	No glow
Uraninite	North Carolina	Fine glow
Uraninite	Joachimsthal, Bohemia	Very faint glow
Uranite	(rare)	No glow
Uranophane	Spruce Pine, Mitchell Co., N. C.	Fair glow
Xenotime	Hitterö, Norway	Faint
Yttro-tantalite	Ytterby, Sweden	No glow
Zeunerite	S. B., Germany	No glow

Substance.	Prepared by	Result.	Remarks.
Uranium carbide	Tucker	No glow	Not expected from our knowledge of the activity of uranium.
Uranium oxide	Tucker	No glow	
Uranium nitrate	Purchased	No glow	
Thorium-X	Miner. From 100 gals. wash-water	Fair glow	
Thorium oxide	Same as for Welsbach burners	Fair glow	Slight glow with tiffanyites. No glow with solid willemite.
Berzelium* oxide	Irwin. Monazite sand	No glow	No glow with tiffanyites.
Thorium* oxide	Davis. Monazite sand	Fair glow	Slight glow with tiffanyites.
Carolinium* oxide	Skinner. Monazite sand	No glow	

*These preparations were made in our laboratory, University of North Carolina. All showed some but not the same radio-activity when tested by the electrical and photographic methods.

ART. XII.— *The Action of Radium Emanations on Minerals and Gems;** by CHARLES BASKERVILLE and L. B. LOCKHART.

KUNZ and Baskerville† have made some interesting observations concerning the action on minerals and gems of radium compounds of the highest activity enclosed within glass, as well as of mixtures of weaker preparations with a limited number of minerals, especially diamonds, willemite and kunzite.‡ Rutherford used willemite most satisfactorily§ for demonstrating to a large audience the condensation of the emanations by means of liquid air. It was thought advisable to subject other minerals, found by Kunz and Baskerville to be fluorescent or phosphorescent, or both fluorescent and phosphorescent under the influence of ultra-violet light, to similar treatment. We wish to express our obligations to Dr. Geo. F. Kunz, who generously provided us with most of the minerals, all of which were authenticated.

The method of testing was as follows: About 0·25 gram of radium chloride, 7000 uranies‖ strong, was placed in a hard glass tube 2^{mm} in diameter, sealed at one end. This was bound to a glass tube, provided with a stop-cock, which was bent so as to reach through one of the two holes in a rubber stopper to the bottom of a test-tube 2^{cm} wide and 15^{cm} deep. Through the other hole was passed a bent tube so that it just projected below the rubber. This tube was provided with a glass stop-cock and connected with an ordinary vacuum pump. The material upon which the action of the emanation was to be determined was placed in the wide test-tube. The tube was then dipped into liquid air contained in a suitable unsilvered Dewar bulb.

On opening the cock next to the pump while it was in operation a good vacuum was produced in the container tube. When this cock was closed, the radium chloride was heated to low redness. The cock between this and the test-tube was opened. The emanations were swept in and condensed. In every case the tube and contents were allowed to remain in the liquid air until they were assumed to have obtained an uniform temperature. All experiments were carried out in the dark and observations were made only after the eyes had become accustomed to the conditions.

* Read before the Washington Section of the American Chemical Society, April 6th, 1904. † Science. ‡ Patent applied for.

§ Address before the American Association for the Advancement of Science, St. Louis, Mo., Meeting, Dec., 1903.

‖ By an "uranie" is meant the radio-activity of metallic uranium, which is taken as the standard.

It was learned that tiffanyite diamonds are quite as sensitive to the action of the emanations as the phosphorescent zinc sulphide. We did not have enough diamonds to change for each experiment, so in each trial a strip of Sidot's blende screen was inserted. This served to show that the emanations had been condensed. We were much surprised to learn on frequent repetition of the experiment that kunzite, which is so responsive to radium, neither fluoresced nor phosphoresced when the emanations were condensed thereon. It is, therefore, responsive to the beta- and gamma-rays only.

Before giving the results of the observations, which follow in tabulated form, it may be well to relate the results obtained in several experiments, the bearing of which upon the question in mind is apparent.

The cooling of zinc sulphide to the temperature of liquid air does not cause it to glow, with or without vacuum. A good vacuum and a sudden releasing of the same does not cause zinc sulphide to glow. But warming it to ordinary temperature after removal from liquid air does cause it to glow brilliantly. Chlorophane and kunzite cooled in liquid air show no phosphorescence.

Action of emanations from radium chloride (7000 activity) on:

Mineral.	Locality.	Result.	Remarks.	With Ultra-Violet Light.
Wollastonite	Harrisville, Lewis Co., N. Y.	Slow to phosphoresce, faint	Tribo-luminescent	Phosphorescent
White wollastonite (with idocrase and pink garnet)	Morelos, Mexico	Glows brilliantly	Loses glow in less than five minutes	Phosphorescent
Wollastonite	Franklin Tunnel, N. J.	Glows brilliantly	Loses glow quickly	Phosphorescent
Pectolite	Havers, N. Y.	Nothing		Phosphorescent
Pectolite	Paterson, N. J.	Nothing		Phosphorescent
Pectolite	Guttenburg, N. J.	Nothing		Phosphorescent
Spodumene	Paris, Me.	Nothing		Nothing
Spodumene (hiddenite)	Alexander Co., N. C.	Nothing		Nothing
Spodumene	U.G., Brazil, S. A.	Nothing		Nothing
Spodumene (kunzite)	Pala, Cal.	Very slight response		Phosphorescent
Willemite	Franklin, N. J.	Glows well	Not so sensitive as zinc sulphide, or tiffanyite; glows with emanations from commercial thorium oxide	Fluorescent and phosphorescent.
Greenockite		Glows strongly	Goes away quickly	Fluorescent
Hyalite	Yellowstone Park	Nothing		Fluorescent
Colemanite	Mono Lake	Nothing		Phosphorescent
Chlorophane	Amherst, Va.	Nothing		Phosphorescent
Tiffanyite	5 Dutch diamonds, 2¼ k.	Glows very easily and brilliantly	Lasts several hours	Phosphorescence prolonged

Art. XIII.—*The Behavior of Typical Hydrous Bromides when Heated in an Atmosphere of Hydrogen Bromide;* by J. Lehn Kreider.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxvii.]

In former papers from this laboratory* the results obtained in the dehydration of certain hydrous chlorides in air and in an atmosphere of hydrogen chloride have been studied and compared. In the present paper the effects of treating typical hydrous bromides in air and in an atmosphere of hydrogen bromide are described.

Hydrous barium bromide has been taken as a type of hydrous salts which when heated in air lose their water without much further decomposition; hydrous magnesium bromide as typical of salts which lose part of their water without much further decomposition and the remainder with simultaneous evolution of hydrogen bromide; and hydrous aluminum bromide as typical of salts which lose their water only with simultaneous loss of hydrogen bromide.

The method of experimentation was very similar to that followed by Gooch and McClenahan† in their experiments with hydrous chlorides.

For these experiments two combustion tubes 30^{cm} in length and 2^{cm} in diameter, set horizontally side by side in a tubulated paraffine bath, served as heating chambers. Each tube was fitted with a thermometer. Portions of the hydrous bromides to be treated were weighed into porcelain boats. One of these boats was inserted in each tube about midway in the bath (heated to a regulated temperature) and below the bulb of the thermometer, so that the temperature to which the material in the boat was submitted might be indicated by the thermometer as accurately as possible. Through one tube was drawn slowly a current of air purified by sulphuric acid, and through the other was sent a slow current of purified hydrogen bromide, generated in a flask by the action of bromine on a heated solution of naphthalene and kerosene, and passed through a purifying apparatus consisting of a tower containing successive layers of red phosphorus and glass wool and a wash bottle charged with a saturated solution of hydrobromic acid. At the end of a definite period, the boat was withdrawn, placed in a desiccator for a suitable interval to cool, and weighed. The residue in the boat was dissolved in water, and the bromine was precipitated by silver nitrate, the silver bromide being weighed on asbestos. In this way it was

*Gooch and McClenahan, this Journal [4], xvii, 365. McClenahan, this Journal [4], xviii, 104.

†Loc. cit.

possible to determine the loss of water and hydrogen bromide from separate portions of the salt under examination, during definite intervals and at fixed temperatures, both in an atmosphere of hydrogen bromide and in air, and to find for each portion under examination what proportion of the total loss was hydrogen bromide and what was water. The tabular statements and the diagrams show the course of decomposition of the various salts for the temperatures indicated.

Hydrous Barium Bromide.

For the experiments with hydrous barium bromide, a well crystallized specimen was prepared by taking commercially pure barium carbonate, dissolving it in hydrochloric acid, precipitating by ammonium carbonate, washing the precipitate, dissolving in hydrobromic acid, and crystallizing and drying the crystals by pressing between filter papers. The analysis of different portions of this salt showed a definite composition, corresponding very closely to theory.

	Found.	Theory.
Ba	41·69%	41·60%
Br	48·05	47·95
$2H_2O$	10·26	10·45
	100·00%	100·00%

The progress of the decomposition of this salt in air and in hydrogen bromide when submitted for a half hour to the temperatures indicated is shown in the accompanying table and diagram.

Here may be noted a gradual loss of water from 70° C. to 160° C., at which point the water is entirely expelled, without an appreciable loss of hydrogen bromide, either in air or hydrogen bromide, and that hydrogen bromide influences the process of dehydration in no marked way. There is nothing to show that any part of the water sustains a peculiar relation to the salt.

Hydrous Magnesium Bromide.

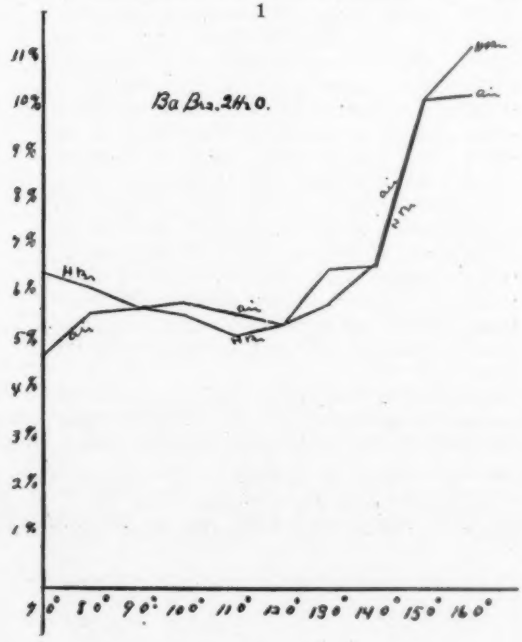
Similar experiments were performed with hydrous magnesium bromide, prepared by dissolving magnesium ribbon in hydrobromic acid and crystallizing the salt over sulphuric acid. The analysis of the salt gave a definite constitution corresponding fairly to theory.

	Found.	Theory.
Mg	08·68	08.27
Br	54·61	54·69
$6H_2O$	36·71	37·04
	100·00	100·00

Dehydration of Hydrous Barium Bromide.

$BaBr_2 \cdot 2H_2O$.

	Atmosphere.	Weight taken.	Loss on heating.		Bromine in residue.			Water evolved.	Time.	Temperature.
		grm.	grm.	per cent.	grm.	per cent.	Variation from theory.	per cent.	hrs.	
1	HBr	·2377	·0165	06·94	·1130	47·56	−0·39	06·55	½	70°C.
	Air	·2364	·0107	04·52	·1141	48·24	+0·29	04·81		
2	HBr	·2309	·0147	06·36	·1105	47·82	−0·13	06·23	½	80°C.
	Air	·2247	·0125	05·56	·1082	48·16	+0·21	05·77		
3	HBr	·2299	·0121	05·26	·1115	48·49	+0·54	05·80	½	90°C.
	Air	·2311	·0127	05·49	·1115	48·26	+0·31	05·80		
4	HBr	·2413	·0121	05·01	·1173	48·58	+0·63	05·64	½	100°C.
	Air	·2416	·0134	05·54	·1167	48·33	+0·38	05·92		
5	HBr	·2399	·0118	04·91	·1157	48·26	+0·31	05·22	½	110°C.
	Air	·2342	·0128	05·50	·1162	48·09	+0·14	05·64		
6	HBr	·2296	·0115	05·00	·1111	48·41	+0·46	05·46	½	120°C.
	Air	·2287	·0127	05·50	·1095	47·91	−0·04	05·46		
7	HBr	·2501	·0157	06·27	·1208	48·32	+0·37	06·64	½	130°C.
	Air	·2472	·0135	05·46	·1195	48·37	+0·42	05·88		
8	HBr	·2389	·0198	06·58	·1147	48·03	+0·08	06·66	½	140°C.
	Air	·2304	·0148	06·42	·1113	48·31	+0·36	06·78		
9	HBr	·2491	·0258	10·36	·1190	47·78	+0·17	10·19	½	150°C.
	Air	·2438	·0251	10·29	·1167	47·86	−0·09	10·20		
10	HBr	·2460	·0269	10·93	·1190	48·37	+0·42	11·35	½	160°C.
	Air	·2416	·0242	10·01	·1166	48·26	+0·31	10·32		



Dehydration of Hydrous Magnesium Bromide.

$MgBr_2 \cdot 6H_2O$.

Atmosphere.		Weight taken.	Loss on heating.		Bromine in residue.		HBr lost.	Water lost.	Time.	Temperature.
		grm.	grm.	per cent.	grm.	per cent.	per cent.	per cent.	hrs.	
1	HBr	·2389	·0000	00·00	·1310	54·81	00·12	00·12	½	70° C.
	Air	·2400	·0000	00·00	·1319	54·98	00·29	00·29		
2	HBr	·1370	·0000	00·00	·0751	54·85	00·16	00·16	½	80°
	Air	·1380	·0012	00·86	·0752	54·55	00·14	00·72		
3	HBr	·1259	·0019	01·50	·0693	54·96	00·27	01·77	½	90°
	Air	·1482	·0023	01·95	·0813	54·87	00·18	02·13		
4	HBr	·1220	·0053	04·34	·0664	54·46	00·23	04·11	½	100°
	Air	·1448	·0048	03·31	·0797	55·07	00·38	03·69		
5	HBr	·1345	·0070	05·20	·0736	54·76	00·07	05·27	½	110°
	Air	·1384	·0103	07·44	·0752	54·33	00·36	07·80		
6	HBr	·1374	·0115	08·36	·0751	54·69	00·00	08·36	½	120°
	Air	·1353	·0120	08·86	·0737	54·50	00·19	08·67		
7	HBr	·1331	·0114	08·56	·0724	54·41	00·28	08·28	½	130°
	Air	·1317	·0128	09·71	·0714	54·28	00·41	09·30		
8	HBr	·1345	·0140	10·40	·0734	54·58	00·11	10·29	½	140°
	Air	·1369	·0183	13·37	·0733	53·59	01·11	12·26		
9	HBr	·1375	·0216	15·71	·0748	54·47	00·22	15·49	½	150°
	Air	·1358	·0251	18·48	·0727	53·58	01·12	17·36		
10	HBr	·1313	·0140	10·66	·0714	54·46	00·23	10·46	½	160°
	Air	·1311	·0324	24·71	·0698	53·26	01·44	23·27		
11	HBr	·1366	·0170	12·44	·0744	54·39	00·31	12·13	½	170°
	Air	·1379	·0159	11·53	·0744	54·00	00·69	10·84		
12	HBr	·1399	·0220	15·72	·0760	54·35	00·34	15·38	½	180°
	Air	·1358	·0232	17·08	·0723	53·27	01·43	15·65		
13	HBr	·1285	·0217	16·89	·0696	54·75	00·06	16·95	½	190°
	Air	·1324	·0275	20·77	·0702	53·06	01·65	19·12		
14	HBr	·1345	·0284	21·11	·0731	54·42	00·27	20·84	½	200°
	Air	·1382	·0312	22·57	·0730	52·87	01·84	20·73		
15	HBr	·1349	·0282	20·90	·0731	54·19	00·50	20·40	½	210°
	Air	·1350	·0331	24·51	·0704	52·20	02·51	22·00		
16	HBr	·1337	·0297	22·21	·0722	54·01	00·68	21·53	½	220°
	Air	·1320	·0379	28·71	·0686	52·03	02·69	26·02		
17	HBr	·1354	·0340	25·11	·0731	54·02	00·67	24·47	½	230°
	Air	·1373	·0606	44·13	·0649	47·43	07·35	36·78		
18	HBr	·1376	·0401	29·14	·0740	53·69	01·01	28·13	½	240°
	Air	·1360	·0555	40·80	·0665	48·93	05·80	35·00		

From these results it appears that approximately a third of the water may be removed from the hydrous magnesium bromide, submitted at once to the temperatures indicated, either in air or in an atmosphere of hydrogen bromide, without considerable simultaneous loss of hydrogen bromide from the salt, the trifling loss being somewhat less in the atmosphere of

hydrogen bromide than in air, Thereafter the loss of hydrogen bromide when the salt is heated in air increases generally with the temperature and is inhibited, as is the loss of water,

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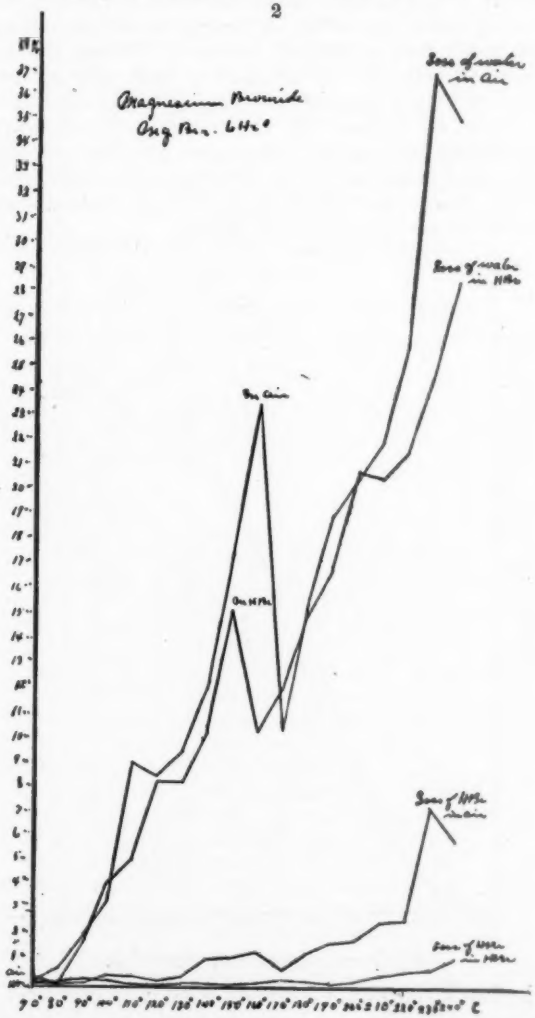
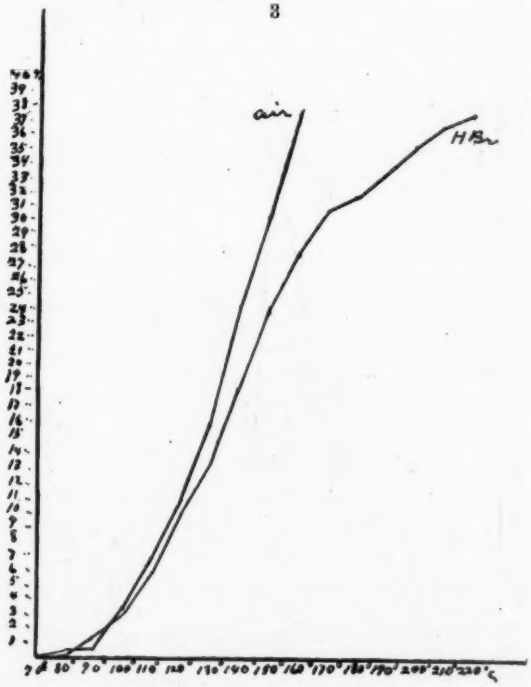


by the atmosphere of hydrogen bromide. It appears that about a third of the water of magnesium bromide bears a relation to the salt different from that of the remainder.

When submitted at once, without preliminary heating, to a temperature of 170° in air and 160° in hydrogen bromide, the hydrous salt melts and in the melted condition loses water less rapidly than the solid salt at a somewhat lower temperature. This is what makes the break in the curves which indicate the losses of water and hydrogen bromide. When the salt was heated successively, for intervals of a half hour, at temperatures varying by ten degrees, the progress of dehydration was more uniform, as is shown in the accompanying diagram, all the water being lost at 160° in air and 220° in hydrogen bromide, the inhibiting action of hydrogen bromide upon the dehydration being more marked as the temperature rises from the point at which the first third is lost.



Hydrous Aluminum Bromide.

The hydrous aluminum bromide used was prepared by dissolving pure aluminum chloride in water, precipitated aluminum hydroxide by ammonium hydroxide, filtering off the aluminum hydroxide, and washing until free from impurities. This precipitate was then dissolved in hydrobromic acid, and

the solution thus formed allowed to crystallize by evaporation in vacuum over sulphuric acid: the crystals thus formed were of nearly normal constitution.

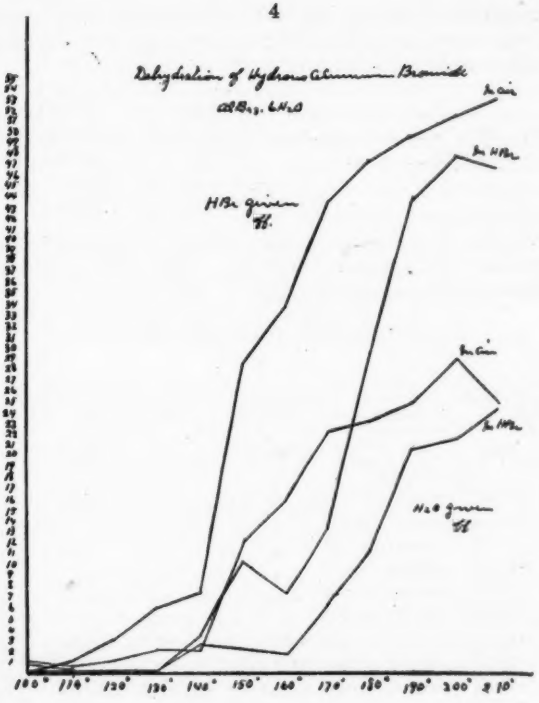
	Found.	Theory.
Al	07·25%	07·20%
Br_3	63.90	63·95
$6H_2O$	28·85	28·85
	100·00	100·00

The course of dehydration of hydrous aluminum bromide in air and in an atmosphere of hydrogen bromide is shown in the accompanying table and diagram.

Dehydration of Aluminum Bromide.

$AlBr_3 \cdot 6H_2O$.

	Atmosphere.	Weight taken.	Loss on heating.		Bromine in residue.		HBr lost.	Water lost.	Time.	Temperature.
		grm.	grm.	per cent.	grm.	per cent.	per cent.	per cent.	hrs.	
1	HBr	·1308	·0000	00·00	----	----	----	----	½	70° C.
	Air	·1306	·0000	00·00	----	----	----	----		
2	HBr	·1394	·0000	00·00	----	----	----	----	½	80°
	Air	·1381	·0000	00·00	----	----	----	----		
3	HBr	·1344	·0000	00·00	----	----	----	----	½	90°
	Air	·1360	·0000	00·00	----	----	----	----		
4	HBr	·1317	·0008	00·60	·0831	63·13	00·83	00·23	½	100°
	Air	·1316	·0014	01·06	·0842	64·05	00·10	01·16		
5	HBr	·1364	·0008	00·58	·0861	63·60	00·35	00·23	½	110°
	Air	·1378	·0024	01·74	·0865	62·83	01·13	00·61		
6	HBr	·1381	·0008	00·57	·0878	63·62	00·33	00·24	½	120°
	Air	·1367	·0054	03·95	·0834	61·07	02·91	01·04		
7	HBr	·1297	·0006	00·46	·0825	63·64	00·31	00·15	½	130°
	Air	·1318	·0106	08·04	·0767	58·24	05·78	02·26		
8	HBr	·1379	·0011	00·79	·0831	60·32	03·67	02·89	½	140°
	Air	·1357	·0127	09·35	·0771	56·85	07·18	02·17		
9	HBr	·1366	·0113	08·27	·0730	53·46	10·62	02·35	½	150°
	Air	·1355	·0549	40·51	·0485	35·84	28·46	12·05		
10	HBr	·1308	·0121	09·25	·0740	56·57	07·43	01·82	½	160°
	Air	·1348	·0668	49·55	·0413	30·66	33·71	15·84		
11	HBr	·1380	·0270	19·56	·0703	50·94	13·17	06·39	½	170°
	Air	·1390	·0919	66·11	·0281	20·72	43·77	22·34		
12	HBr	·1378	·0561	40·71	·0477	34·65	29·67	11·04	½	180°
	Air	·1346	·0949	70·50	·0232	17·28	47·26	23·24		
13	HBr	·1331	·0850	63·86	·0280	21·09	43·40	20·46	½	190°
	Air	·1307	·0976	74·67	·0193	14·80	49·72	24·95		
14	HBr	·1362	·0938	68·87	.0232	17·08	47·46	21·41	½	200°
	Air	·1377	·1090	79·15	·0197	14·33	50·24	28·91		
15	HBr	·1355	·0958	70·70	·0246	18·04	46·49	24·21	½	210°
	Air	·1345	·1040	77·32	·0158	11·76	52·85	24·47		

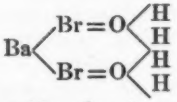


From these results it appears that, at 100° and higher temperatures, hydrous aluminum bromide loses water and hydrogen bromide simultaneously, both in air and in an atmosphere of hydrogen bromide; but that the loss of water, as well as of hydrogen bromide, from the salt is retarded by the atmosphere of hydrogen bromide. At the highest temperature recorded, 210° C. the salt still retained bromine. There is nothing to indicate that any part of the water possesses a different relation to the salt from that possessed by any other part of the water.

Discussion of Results.

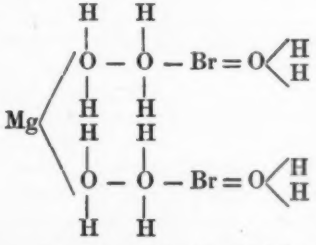
In correlating the phenomena noted, Cushman's hypothesis of inner and outer linkages of water relative to the molecular complex, upon the assumption of quadrivalent oxygen, seems applicable.

Thus the symbol



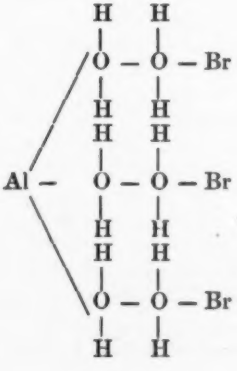
for hydrous barium bromide, showing two molecules of water externally attached, suggests the observed easy removal of all water without simultaneous loss of hydrogen bromide, and indicates, as was observed, that concentration of hydrogen bromide in the system is not likely to affect the course of dehydration.

The symbol



for hydrous magnesium bromide, in which two molecules of water are externally attached and four internally, shows why one-third of the water may be removed at a moderate temperature, without much loss of hydrogen bromide; why the remaining two-thirds of the water require a higher temperature for their removal with simultaneous evolution of hydrogen bromide; and why increase in the concentration of hydrogen bromide in the system retards both the loss of water and hydrogen bromide, after the first third of the water has been expelled.

The symbol



for hydrous aluminum bromide suggests the observed impossibility of evolving water without simultaneous loss of hydrogen bromide, the salt tending on continued heating to go over to the oxide. With a salt showing this constitution the natural effect of the concentration of hydrogen bromide in the system would be to retard the dehydration of the salt, as was observed.

So it appears that the phenomena of dehydration of the hydrous bromides under discussion admit of explanation upon Cushman's hypothesis of the molecular attachment of water within and without the complex.

The author is greatly indebted to Prof. F. A. Gooch for advice and assistance throughout this work.

Art. XIV.—*The Glacial (Dwyka) Conglomerate of South Africa;* by Edward T. Mellor.

[Communicated by permission of the Director of the Geological Survey of the Transvaal.]

Introductory.—Few rocks have aroused so widespread and so sustained an interest as the Glacial Conglomerate occurring at the base of the Karroo System of South Africa, generally known as the Dwyka Conglomerate. From the time when attention was first directed to it by Bain in 1856, down to the present, the Dwyka Conglomerate has continued to be a source of almost continual discussion.

In the first instance, this interest was in a great measure due to the very different views held by various geologists as to the nature of the conglomerate, and especially to the opposition offered by many to the theory of its glacial origin—a question which one may venture to regard as finally settled by the accumulation of evidence in recent years. This establishment of the glacial character of the deposits included under the term Dwyka Conglomerate, which occur over thousands of square miles in South Africa, and which correspond closely with similar formations of corresponding age in India, Australia, and South America, lends a newer and perhaps more widely spread interest to the study of this series, and of the conditions under which it was formed. To the South African geologist the rock derives additional interest from the fact that it affords the only geological horizon common to the various colonies yet established with any degree of certainty.

Nomenclature.—The term "Glacial Conglomerate" was used by E. J. Dunn on his map published in 1873* for the northern outcrops of the conglomerate, while he still retained for the more southerly occurrences an old name, "Trap Conglomerate," used by Wyley. In the second edition of his map,† two years later, while retaining the term Glacial Conglomerate for the northern outcrops, Dunn applied the term "Dwyka Conglomerate" to those of the southern parts of Cape Colony and Natal. The term Dwyka is derived from a river of that name in Cape Colony in the neighborhood of which the conglomerate is typically developed. The name is now frequently applied to the glacial conglomerate at the base of the Karroo System generally throughout South Africa. It might perhaps be more appropriately restricted to the southern type, which, as will be pointed out, differs in some important respects from the more northerly occurrences, especially as the intermediate

*E. J. Dunn, Geological Sketch Map of Cape Colony, London, 1873.
† E. J. Dunn, Geological Sketch Map of South Africa, London, 1875.

phases have not yet been fully worked out. For the northern conglomerates the original term "Glacial Conglomerate" is as appropriate as ever, and I have preferred it in various descriptions of these conglomerates in the Transvaal.

Distribution of the Conglomerates.—The main area occupied by the Karroo System covers a large part of South Africa, including the major portions of Cape Colony and Natal, nearly the whole of the Orange River Colony and most of the south-eastern Transvaal. This area would be included roughly between lines drawn from a point on the south-east coast of Cape Colony, near to the mouth of the Gualana River, W. to near the head of the Doorn River beyond Matjesfontein, NNE. to the Lange Berg on the southern border of Namaqualand, NW. by Prieska and Kimberley to Middelburg and Belfast in the Transvaal, SSE. by Amsterdam to Vryheid, and SSW. to the coast of Cape Colony at the mouth of St. Johns River. This area includes most of the higher portions of South Africa, and almost the whole of it lies above a level of 3000 feet. In the Drakensberg the uppermost portions of the Karroo System attain an elevation of over 8000 feet.

The series of glacial deposits at the base of the system crop out almost continuously around the margin of the vast area occupied by it, following approximately the lines given above. Along their southern margin the Karroo rocks, particularly the Dwyka Conglomerate, have been affected by the intense folding characteristic of the southern portions of Cape Colony. There the lowest Karroo Beds are frequently highly inclined, and their outcrop is correspondingly reduced in width, but over the whole of the remainder of the area occupied by them the Karroo rocks are practically horizontal, and the outcrops of the various divisions occupy broad tracts of country. This is especially the case with the Glacial Conglomerate and lower portions of the system, which in many places form extensive outliers around the margin of the main area as above defined.

Relationships and Age.—In its southern portions in Cape Colony the Dwyka Conglomerate grades downwards into a series of greenish shales (Lower Dwyka Shales) some 700 feet in thickness, which in turn lie comformably upon the quartzites of the Witteberg Series. These, together with the Bokkeveld Beds and the Table Mountain Series, constitute the "Cape System" of Cape Colony.

Passing northwards, the Dwyka Series overlaps the lower divisions of the Cape System, which thin out in that direction, and comes to lie unconformably upon various much older systems of rocks. In all the more northerly localities where the conglomerate has been studied, it lies uncomformably on the older South African rocks, the surfaces of which are fre-

quently glaciated. In Cape Colony and Natal the Dwyka Conglomerate passes upwards into the Ecca Shales, a series of shales and mudstones identical in character with the shales occurring with the Dwyka Conglomerate, and in composition corresponding with the finer portions of the matrix of that rock. The Ecca shales are succeeded by a very extensive series of sandstones and shales, attaining a maximum thickness of some thousands of feet, and including on at least two different horizons seams of coal. These, together with the Ecca Shales and Dwyka Conglomerate, constitute the Karroo System of South Africa. Intrusive sheets of diabase occur throughout the Karroo rocks, and the uppermost portion of the system consists, for the most part, of a succession of lava-flows usually amygdaloidal and of basaltic composition interbedded with sandstones containing much fragmental material of volcanic origin.

The Bokkeveld Beds of Cape Colony have yielded a numerous assemblage of fossils related to the Devonian fauna of Europe; the Witteberg beds which succeed them and underlie the Dwyka Series have so far afforded only a few imperfect specimens showing general Carboniferous affinities. With the Ecca Shales in Cape Colony and with the beds associated with the Coal Seams of the Transvaal, which sometimes, as at Vereeniging, lie immediately above the Glacial Conglomerate, a fossil flora is associated of Permo-Carboniferous age* having a number of genera in common with the lower part of the Indian Gondwana System, and the Coal Measures of New South Wales.

Compared with the southern and eastern margins of the Karroo area, the northern outcrops of the Glacial Conglomerate and associated beds show a considerable diminution in thickness, a feature shown also by the other divisions of the Karroo System. In the southern outcrops in Cape Colony the Dwyka Conglomerate has a thickness of about 1000 feet; on the north of the Colony, in the neighbourhood of Prieska, it is stated not to exceed 500 feet.† In Natal and the eastern Transvaal the thickness of the conglomerate is about 300 feet,‡ while on the northern border of the formation, in the central portions of the Transvaal, it rarely reaches 100 feet, and may be locally absent altogether. As will be seen from the descriptions given below, this difference in thickness corresponds with differences in composition, and in general characters dependent upon variations in the original conditions of deposition in the different localities.

* A. C. Seward, Notes on the Plant Remains from Vereeniging, Q. J. G. S., vol. liv, pp. 92–93. London, 1898.

† A. W. Rogers, The Geology of Cape Colony, London, 1905.

‡ G. A. F. Molengraaff, Geology of the Transvaal, Edinburgh, 1904, p. 73.

Description of the Dwyka Conglomerate in the Southern Outcrops.—The earlier studies and descriptions of the Dwyka conglomerate were confined to its occurrence in the southern portions of Cape Colony and in Natal. In the southern examples especially the conglomerate has certain characteristics which led to much controversy as to its origin. Its appearance in the Dwyka locality was thus described by Mr. E. J. Dunn:* "The conglomerate consists of a bluish grey base so fine that its constituents are not resolvable, except under high magnifying power, and then no crystals are disclosed; it appears to be a very fine indurated mud; in this base are enclosed bowlders, pebbles, angular fragments, and grains of a great variety of rocks, such as granite, granulite, gneiss, mica, and other schists, quartz rock, hard sandstone, jasper, hornfels, quartz, small pieces of felspar, etc."

The included fragments, which range in size from mere grains to bowlders several feet in diameter, are distributed in the matrix without definite arrangement. The rock as a whole is very hard and fractures pass indifferently through matrix and bowlders alike. By weathering it frequently produces a yellowish clay, through which the hard rock fragments and bowlders of the original conglomerate are scattered. Besides the conglomerate beds, other shaly beds occur devoid of included fragments. Individual beds persist over long distances, maintaining at the same time their distinctive lithological characters. The conglomerate beds vary from a few inches to hundreds of feet in thickness. In the southern parts of Cape Colony the conglomerate often shows a schistose structure resulting from the earth movements which have affected that area—to the effects of which is probably also due in part the extreme hardness of the southern rock as compared with its northern representative.

Various theories concerning the Origin of the Dwyka Conglomerate.—The dark green color of the conglomerate, its richness in minerals not usually abundant in rocks of sedimentary origin, including much chloritic material, its extreme hardness, its crystalline appearance and the frequent absence of bedding through great thicknesses of rock, disposed almost every observer, including many geologists of wide experience, to attribute to the conglomerate an igneous origin. Expressive of these views are the following names applied to the rock at various times by different workers: "Claystone-porphyry," "Trap-conglomerate," "Melaphyre-breccia," "Volcanic-breccia," "Trap-breccia." Many and various were the theories advanced at different times and by different observers to

* E. J. Dunn, Report on the Camdeboo and Nieuwveldt Coal, p. 7, Cape Town, 1879.

account for the peculiar characters of the conglomerate. A. G. Bain, "The Father of South African Geology," who first described the Dwyka Conglomerate in 1856, suggested that it represented a flow from an immense volcano. Prof. A. H. Green thought it to be a "coarse shingle formed along a receding coast-line," while from Green's specimens Sir A. Geikie and Dr. F. H. Hatch considered it had the aspect of a volcanic breccia. The majority of South African geologists favored the igneous theory, accounting for its peculiar characters and occasional stratification by referring its origin to submarine volcanoes.

A glacial origin was first attributed to the conglomerate in 1868 in a paper on the Geology of Natal by Dr. P. C Sutherland,* who had previously regarded the rock as a lava-flow. Sutherland, who was familiar with the conglomerate in Natal, where the rock has more the features of a terrestrial glacial deposit, and rests in places upon striated rock surfaces, clearly stated the real character of the rock. The glacial view received early support from Stow,† who, however, referred the glaciation to a much later period, and subsequently from Schenck.‡ Dunn, who did so much to work out the main features of the distribution of the Glacial Conglomerate as shown in the various editions of his "Geological Sketch Map of South Africa," regarded the rock as largely due to the action of floating ice, an agent which no doubt had much to do with the southern deposits.

It is only quite recently, however, that owing to the accumulation of evidence§ from various localities in South Africa the glacial origin of the Dwyka Conglomerate has received anything approaching general acceptance.

Recent Studies of the Glacial Conglomerate.—In 1898 Dr. Molengraaff‖ published a description of the Dwyka Conglomerate, and overlying Ecca beds, as developed in the Vryheid district of the Transvaal, to the north of the Natal border (now included in the latter colony). In the Vryheid district the Dwyka Conglomerate averages about 300 feet in thickness, and lies unconformably upon an old land surface composed mainly of the hard quartzites and shales of the Barberton formation—the surfaces of which are frequently polished and striated. Both the conglomerate and succeeding Ecca Shales offer good

* P. C. Sutherland, On the Geology of Natal, Pietermaritzburg, 1868.

† G. W. Stow, On some Points in S. A. Geology, Q. J. G. S., vol. xxvii, pp. 497–548. London, 1871.

‡ A. Schenck, Die Geologische Entwickelung Südafrikas, Pet. Mitt., Band xxxiv. Gotha, 1888.

§ See recent reports of the Geological Surveys of Cape Colony, Natal and the Transvaal.

‖ G. A. F. Molengraaff, The Glacial Origin of the Dwyka Conglomerate, Trans. Geol. Soc. S. A., vol. iv, 1898.

opportunities for study in the many sections exposed in the deeply cut valleys of the eastern rivers. In this district the Dwyka Conglomerate includes both unstratified and stratified portions, in each of which facetted and striated bowlders are abundant, together with many angular and sub-angular rock fragments. The stratified beds are sometimes almost devoid of bowlders and pebbles, and include mudstone and shales, the latter indistinguishable from the overlying Ecca Shales into which the Dwyka Conglomerate gradually passes.

In 1899 Messrs. Rogers and Schwartz* studied the Glacial Conglomerate in the Prieska district in the north of Cape Colony. They found the Conglomerate here to present all the features of a true ground moraine, with abundance of facetted and striated bowlders; and lying unconformably upon all the older rocks of the district, fragments of which occur in the conglomerate and which afford fine examples of "roches montonnées" and striated surfaces. The direction of the striæ and distribution of the bowlders point to a movement from the north southwards.

In his report for the same year Dr. Corstorphine† summed up the results obtained in the north and south of Cape Colony and elsewhere, and compared the features of the northern and southern deposits, contrasting the northern Glacial Conglomerates, possessing the characters of a ground moraine, with the southern Dwyka, which is to be looked upon as "a sediment formed under a probably inland water, into which there floated the icebergs calved from the front of the glacier or glaciers on the northern shore."

The identity in character of the Glacial Conglomerate with a true ground moraine, seen in the northern parts of Cape Colony, comes out with even greater clearness along the northern edge of the main area occupied by the Karroo System in the Transvaal.

The Glacial Conglomerate in the Transvaal.—In the central portions of the Transvaal, and particularly in a district lying along the eastern railway line from Pretoria to Middelburg, I have recently mapped many outliers of Karroo rocks isolated by the progress of denudation from the main body, which covers extensive areas to the south and south-east. These outliers sometimes include portions of the sandstones, grits, and shales associated with coal-seams which form the upper portion of the Karroo System as developed in this part

* Rogers and Schwartz, Ann. Rep. of the Geol. Commission, 1899. Cape Town, 1900. On the Orange River Ground Moraine. Trans. Phil. Soc. S. A., vol. xi, part 2, 1900.

† G. S. Corstorphine, Ann. Rep. of the Geol. Commission, 1899. Cape Town, 1900. (Full references to the previous literature will be found in this paper.)

of the Transvaal. They are, however, frequently reduced to patches consisting almost entirely of the Glacial Conglomerate and associated beds. The copious sandy drift shed by these outliers frequently renders their examination difficult, but in some cases they offer more than usually good opportunities for the study of the Glacial Conglomerate and its relationships to the underlying rocks. In the district here more especially referred to, the glacial deposits consist for the most part of a conglomerate showing all the characters to be expected in one formed beneath an extensive ice-sheet. This conglomerate is

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very irregular in distribution, and varies greatly in thickness within short distances, partly in consequence of its original deposition on an irregular land surface, and partly as a result of subsequent denudation. Its average thickness is about fifty feet. In depth the rock is sometimes greenish in color, but at the surface it is usually light yellow, and crops out in characteristic humpy masses (see fig. 1). The matrix is a sandy-looking material consisting of sharply angular fragments of quartz and of various rocks—quartzites, hard shales, felsites, granophyres—common in the district. These angular fragments vary in size from the smallest particles to pieces several inches in diameter. Irregularly distributed through the matrix, and with a conspicuous absence of any sort of arrangement as to size or orientation, occur abundant pebbles and

bowlders of very miscellaneous composition, and ranging in size up to a diameter of eight or ten feet. These pebbles and bowlders are frequently facetted, and those of very hard materials are always highly polished, while bowlders of somewhat softer nature, especially if fine in grain, such as hard shales and weathered felsitic rocks, frequently show striations. A network of cracks in some cases divides the pebbles into a number of fragments which have been again cemented into a whole. In any particular locality there is always a preponderance of bowlders derived from rocks which locally underlie the Glacial Conglomerate, associated with others easily recognizable as derived from more distant sources, which are always to the north of the present position of the bowlders. Thus along the eastern railway line, to the south of an area mainly occupied by the Waterberg Formation and the Red Granite, the Glacial Conglomerate contains an abundance of bowlders derived from these rocks. South of the outcrop of the hard white Magaliesberg quartzites, fragments of the white quartzites are very abundant. Those lying nearest to the ridge from which they were derived are angular and frequently of huge dimensions, so that when weathered out and lying on the surface they are conspicuous objects at a distance of two or three miles. On the eastern Witwatersrand the conglomerate contains many bowlders derived from the Rand Series together with others formed of the hard cherts of the Dolomite to the north. Except quite locally, the lower and more massive portions of the conglomerate rarely show any traces of bedding, but are occasionally traversed by irregular partings dividing the rock into rude sheets with undulating billowy surfaces. Towards the upper portions of the conglomerate, lenticular beds of fine-grained massive sandstone frequently occur, together with patches of white and cream-colored shales and mudstones. The shales appear to have been formed in local pockets below the ice. They consist of the finest glacial mud. The examination of a district of some hundreds of square miles in extent leads to the conclusion that at the termination of the period during which glacial conditions obtained, the country was left covered with an almost complete mantle of glacial deposits, quite similar in character and distribution to those remaining in other parts of the world from extensive glaciation of more recent date. After the cessation of glacial conditions the conglomerates and associated deposits appear to have suffered a certain amount of sub-aërial erosion and denudation, during which materials derived from the glacial deposits underwent re-arrangement and re-deposition, giving rise in some cases to beds of conglomerate very similar in composition and general appearance to those of glacial origin, with

which they are liable to be confused, but differing in the more orderly arrangement of their materials, including a definite orientation of the pebbles and bowlders. These secondary conglomerates occasionally occur at the base of the purely sedimentary series which succeed the true glacial deposits, and by which as a result of a period of long continued subsidence the latter were ultimately entirely covered. This sedimentary series included the succession of beds constituting in the Transvaal area the upper portion of the Karroo System. Later formations were also possibly represented but of these no ves-

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tige has hitherto been discovered in the Transvaal. Raised subsequently to an average elevation of 5000 feet above the sea, the Karroo System has been again subjected to denuding forces and the removal of the overlying sandstones, shales, and grits of the Coal Measures has laid bare extensive areas of the underlying Glacial Conglomerate.

Although modified by the double process of denudation to which it has been subjected, it still presents in its distribution a striking similarity to that of more recently formed glacial deposits. Following the contours of the land surfaces upon which it was originally laid down, it ranges within distances of a few miles through variations in elevation of three to five hundred feet. It is frequently well developed on one slope of a hill and entirely absent from the other. When protected

from erosion it fills preëxisting valleys, and is usually especially abundant below ancient escarpments of the older rocks, and in such places bowlders often of very large size, attaining in some cases eight or ten feet in diameter, are exceptionally numerous. After the complete weathering away of the matrix the bowlders remain abundantly scattered over areas previously occupied by the conglomerate. (See fig. 2.)

Glaciated Surfaces below the Conglomerate—Direction of Ice-Movement.—The progressive removal by denudation of the Glacial Conglomerate around the margins of the areas now occupied by the Karroo System and its outliers continually lays bare fresh portions of the underlying old land surface. Where these include outcrops of hard and moderately fine-grained rocks, the latter frequently present excellent examples of glacially striated surfaces,* some of which are represented in the photographs reproduced in figures 3, 4, 5. Striated surfaces of this kind were long ago described by Sutherland in Natal, by Griesbach in the same colony, by Dunn and Schenck in the neighbourhood of the Vaal River, and more recently by Molengraaff in the South-Eastern Transvaal, and by Rogers and Schwartz in the Prieska district in the north of Cape Colony. While working on an area lying about 25 miles east of Pretoria in 1903, I found the surface shown in figure 3, and later those in figures 4 and 5. These latter occur on the edge of an outlier of Karroo rocks some 25 miles further east, which includes the coal seam worked at the Douglas colliery. I have since met with many similar surfaces distributed over an area of some 300 square miles. The striation in most cases is exceedingly clear, and the direction of ice-movement easily determined and remarkably consistent. In all the examples found it only varies within a few degrees from magnetic north and south, the direction of movement being in a southerly direction, which is also true in general for the other districts in South Africa where striated surfaces have been found. This consistency of direction over so considerable an area and in the case of surfaces lying 25 miles apart, points to the existence of an ice-sheet of considerable magnitude, rather than to that of a number of more or less isolated glaciers, a conclusion which is supported by the nature of the land surface laid bare by the disappearance of the Karroo deposits.

Where the Waterberg Sandstone Formation, which occupies much of the district here referred to, has been long exposed to ordinary denudation, the rivers cut deep valleys and gorges in the sandstone, giving rise to very varied and occasionally rug-

* E. T. Mellor, On Some Glaciated Land Surfaces occurring in the District between Pretoria and Balmoral. Trans. Geol. Soc. S. A., vol. vii, part 1, 1904.

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ged scenery. Where, however, the overlying Glacial Conglomerate is only now in process of removal, the country retains the rounded outlines characteristic of a glaciated landscape.

Northern extension of the Glacial Conglomerate.

I have recently met with good examples of the Glacial Conglomerate much further to the north than any hitherto described.* (Figures 1 and 2.) These are situated near the junc-

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tion of the Elands and Olifants Rivers, about 90 miles north of the latitude of Johannesburg, and are interesting for the additional light they throw upon the northward extent of the country subjected to glacial action in early Karroo times.

EXPLANATION OF FIGURES.

FIGURE 1.—Glacial conglomerate near the junction of the Elands and Olifants Rivers, Transvaal (75 miles NE. of Pretoria).

FIGURE 2.—Weathered-out Glacial conglomerate, same locality. The figure stands upon grits of the upper Karroo formation.

FIGURE 3.—Glaciated surface. Elands River Valley (25 miles E. of Pretoria).

FIGURES 4 and 5.—Glaciated surfaces north of Balmoral (50 miles E. of Pretoria).

The striated rocks are red quartzitic sandstones of the Waterberg Series.

Geological Survey, Pretoria, Transvaal.

*E. T. Mellor, Outliers of the Karroo System near the Junction of the Elands and Olifants Rivers in the Transvaal, Trans. Geol. Soc. S. A., vol. vii, part 3, 1904.

Art. XV.—*The Formation of Natural Bridges;* by Herdman F. Cleland.

Until recently the text-books of Geology and Physical Geography have given the idea, whether intentionally or not, that natural bridges are universally formed by the partial caving in of a long cavern, the bridge being that portion of the roof strong enough to span the cavity.* The belief seems to be prevalent that these cavities extended for long distances, a condition comparable to that which would exist if the greater part of the roof of Mammoth Cave should fall in, leaving a small portion as a bridge. This theory is simple and logical and is one which immediately appeals to the reader, but, as will be seen from the examples cited in this paper, not only is it not of universal application but it must be exceptional rather than otherwise. The writer was led to this study by an examination of the natural bridge near North Adams, Mass. which has long been considered to be a typical example and proof of the formation from caverns.

The North Adams Natural Bridge spans Hudson Brook and has been an object of more than local interest for many years both because of its natural beauty and because of the rarity of these objects. Hudson Brook is a small stream emptying into Beaver Creek, a tributary of the Hoosick River. From the dam (shown in the sketch fig. 1) to the pre-glacial valley the brook flows through a gorge 30 to 60 feet deep and from 5 to 40 feet wide, the average width above the bridge being from 1 to 10 feet and below from 10 to 30 feet. This gorge is cut in a coarsely crystalline marble which, because of its color and texture, presents a striking appearance. The rock is Cambro-Silurian and belongs to the Stockbridge formation.

The top of the natural bridge is 44 feet above the water of the stream and the bridge itself is about 8 feet thick. The span of the bridge is less than 10 feet long and the width at present 25 feet, but at one time it probably extended a short distance farther south where it is now fallen in. It is extremely difficult to take a good photograph of the bridge because, as will be seen from the sketch, the stream turns sharply both above and below. Because of this condition it was found necessary to make a drawing, in order to give a correct idea of its appearance.

Prof. E. Hitchcock described the North Adams Natural Bridge and published a rough drawing of it in 1841.† Concerning this drawing he says, "I thought it better that a sketch

* Chamberlain and Salisbury, Geol., vol. i, pp. 145–147.

† Geology of Mass., by Edward Hitchcock, vol. i, 1841, pp. 287–288.

should be taken by one not at all accustomed to drawing, than that no memento be left of this interesting place," (there was danger at that time that the bridge might be destroyed by the quarry-men.) Hovey* in his "Celebrated American Caverns" describes this bridge but gives the locality as Adams, Mass.

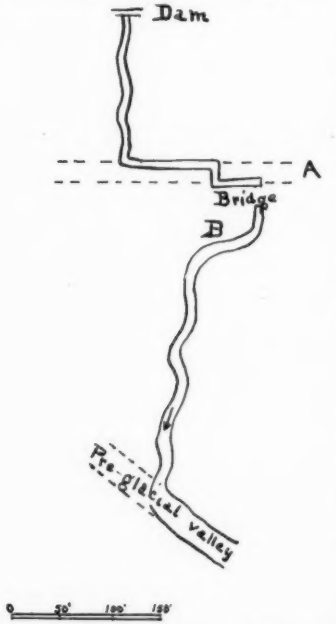


FIG. 1.—Sketch map of Hudson Brook, Mass., showing the position of the natural bridge, the joint planes A-A, and the pre-glacial valley.

The explanation of the formation of the North Adams Natural Bridge, as given by Hitchcock and accepted by Hovey, is that it is the section of the roof of a cavern, the ends of which have fallen in. In illustration of this point, Hovey states that, "the combination of cave, chasm and natural bridge, on Hudson Brook, Mass. is even a better example (than that of the Natural Bridge in Virginia) of the same thing," i. e., "that what are now open canons were once caves, the arch being merely a remnant of an ancient cave roof."

On examining the course of the stream and the rock in the vicinity of the North Adams Natural Bridge one is struck with the width of the joints, and the fact that the stream has, for a portion of its course, followed the joint planes. In the upper part of the accompanying sketch (fig. 1) the relation of the stream to the joint planes is indicated by the dotted lines A–A. The channel through which the stream flowed previous to the formation of the bridge is also well marked a few feet to the west at B. A pot-hole situated near the edge of the gorge at B is further evidence of the former position of the brook.

The bridge was probably formed as follows: When the stream flowed into the gorge through the ancient channel, it plunged over a fall into the pre-glacial valley. Some of the water in the joint plane nearest the present bridge seeped through an approximately horizontal crack a short distance under the present arch of the bridge. The solvent power of

* "Celebrated American Caverns," H. C. Hovey, pp. 14 and 206.

the water containing carbon dioxide (CO_2) gradually increased the size of the crack until it was still further enlarged by the erosion of the stream. The stream was finally entirely diverted from its former channel at B to its present course. The gorge from the dam to the pre-glacial valley is a succession of broken pot-holes varying in size up to 6 or 8 feet in diameter, showing

FIG. 2.—The North Adams Natural Bridge as seen from the south. Formerly the bridge probably extended nearly to the foreground of the picture.

that after the tunnel was made the gorge was largely excavated in this way. The pre-glacial valley in which the Hudson Brook flows below the gorge is broad but to some extent choked with glacial drift.

The origin of the famous Natural Bridge of Lexington, Va.,* as explained by Walcott, was similar to that of the Natural Bridge of North Adams, Mass., but is on a larger scale. Before

* National Geographic Magazine 1893, vol. v, p. 59.

the formation of the bridge the stream, which now flows under, then flowed upon the surface of what is now the arch and probably plunged over a fall a short distance below the present site of the bridge. While the stream was flowing over this fall a portion of the water was percolating through a joint plane or other crack up stream and discharging into the stream under the fall, enlarging its passage by its solvent power. In the course of time this passage became sufficiently large to contain all of the water of the stream, and the bridge resulted. It is not possible to say what the length of this underground passage was. It must have been somewhat longer than at present, but "whether one hundred feet or several hundred feet" it is not possible to determine.

The description of some wonderful natural bridges in Utah,* in a recent paper, suggests an explanation similar to that given above, except that, in the case of these bridges, the rock is said to be a sandstone (pink or gray) instead of a limestone. The most probable explanation is that, at one time, the river flowed over a fall a short distance below the lowest bridge and that, as the stream was cutting back, a portion of the water was pouring through a fissure up the stream and reappearing at the brink of the fall, dissolving out the cement of the sandstone along its course. This underground passage was gradually enlarged by the washing out of the unconsolidated sand, resulting in a tunnel of sufficient size to hold the entire volume of the stream. After this event the valley was eroded to nearly its level. This process was repeated three times with the formation of three bridges. When it is remembered that one of these bridges spans a canyon 335′ wide, that the lower side of the arch is 357′ above the stream and that the material of which they are constructed is sandstone, it will be seen that any explanation requiring a tunnel of great size extending for a long distance is untenable. It is, however, unsafe to do more than speculate upon the formation of these bridges, since so little is known of the rock of which they are composed.

In the Yellowstone National Park occurs a small natural bridge of rhyolite. The bridge consists of two vertical slabs of lithoidal rhyolite, parts of the contorted layers of lava flow, which stand nearly vertical in this place.† They are slightly curved and are separated by open crevices with roughened scoriaceous walls. Of the two slabs forming the ledge the eastern is two feet thick at its ends and thinner in the middle. There is a space of two feet between it and the western slab, which is four feet thick. "The span of the arch is about 30 feet and it rises about 10 feet, the top of the bridge being some

* W. W. Dyar, Cent. Mag., vol. lxviii, 1904, pp. 505–511.

† Geol. of Yellowstone Nat. Park, U. S. G. S. Mon., vol. 32, pt. II, pp. 386–7.

40 feet above the stream." The explanation of the formation of the bridge is as follows: The stream which flows underneath

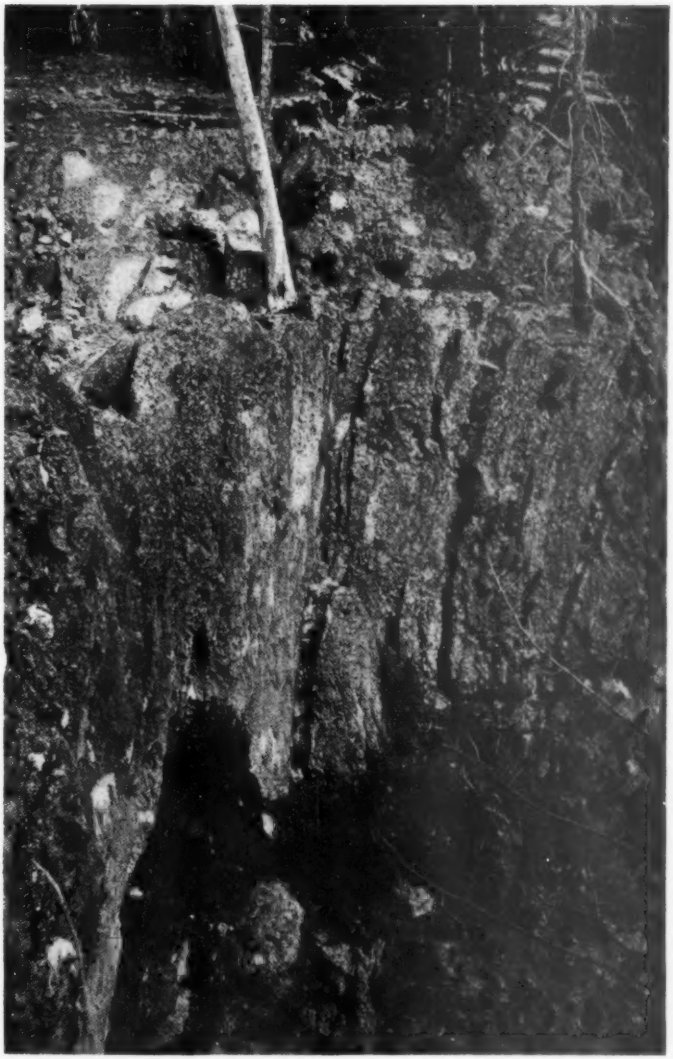


FIG. 3.—Vertical plates of rhyolite. Yellowstone Natural Bridge. (Mon. U. S. G. S. 32, pt. II, plate 49.)

the bridge has been able to excavate, owing to a former waterfall and the peculiar platy structure of the rhyolite, in which curved layers of extremely different physical texture and friability offered a favorable site for attack by frost and water.

The formation of lava bridges is usually explained as follows: The surface of a lava flow cools and hardens while the interior is still in a molten condition. As a result of this condition, if the molten rock beneath continues to flow, a tunnel will result. Such tunnels are of common occurrence on Mt. Vesuvius, the volcanoes of the western states and in other volcanic regions. From such a tunnel a bridge might be formed by the caving in of the greater part of the roof. A study of the photograph (fig. 3) showing the structure of the lava of which the Yellowstone Natural Bridge is formed shows that such an explanation is untenable in this case at least, the rock being composed of approximately vertical plates of lava of different degrees of compactness. The writer has not made a study of other lava bridges, but it seems probable that the mode of formation of the Yellowstone bridge may be exceptional for bridges of this character.

In each of the cases cited the top of the bridge was formerly a portion of the bed of the stream. If natural bridges were formed as commonly supposed, it would be unusual to find that a surface stream had once been superimposed upon the cavern for its entire length. There is, for example, seldom any relation between the surface topography of a country and the underground passages of extensive caves.

Occasionally a small natural bridge occurs near the opening of a cavern or where a spring flows from beneath a cliff. Such a bridge is the sandstone arch spanning a spring which emerges from beneath the sandstone capping of Lookout Mountain near Chattanooga, Tenn. The bridge is formed by the widening of a transverse joint, first by weathering alone and later by the combined action of weathering and erosion, thus separating the bridge from the cliff. The breadth of the span was increased largely by weathering.

The conclusion to which one is led by this study of natural bridges from different parts of the United States and composed of various kinds of rocks—marble, limestone, sandstone, and lava—is that, although bridges may be formed, and undoubtedly have occasionally been formed, by the partial falling in of the roof of a long underground tunnel, the usual mode of formation is that described above. It should, however, be said that examples exist concerning which it is difficult to say which mode of formation was the more prominent.

Williams College.

Art. XVI.—*Quartz from San Diego County, California;** by G. A. Waring, Stanford University, California.

In quartz crystals occurring in the pockets of the gem-bearing pegmatite veins of the Pala and Rincon districts, San Diego County, California, several peculiarities of crystallization have been observed, which it is believed have not before been described. These crystals occur attached to the sides of the cavities, associated usually with albite and orthoclase. The most remarkable feature about them is the common development of tetartohedral faces.

On two crystals, figs. 3 and 7, the facial angles were measured by means of a Fuess reflecting goniometer, and the following rare faces determined, according to Bravais-Miller system of notation.

On the small crystal, fig. 7:—

	Measured.	Given by Dana.
$m \wedge \Gamma\ (40\bar{4}1)$	11° 12′	11° 8′
$m \wedge x\ (51\bar{6}1)$	11° 50′	12° 1′

On the crystal, fig. 3:—

	Measured.	Given by Dana.
$m \wedge x\ (51\bar{6}1)$	11° 27′	12° 1′
$m \wedge y\ (41\bar{5}1)$	14° 8′ 14° 54′ 14° 10′	14° 35′
$m \wedge s\ (11\bar{2}1)$	37° 39′	37° 58′

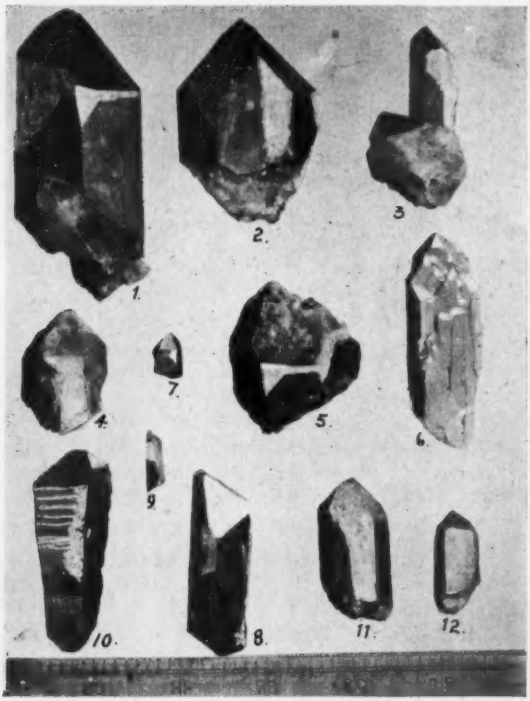
The $\Gamma\ (40\bar{4}1)$ and M $(30\bar{3}1)$ faces also are present on this crystal, determined by measurement with the contact goniometer, and the u-face $(31\bar{4}1)$ is also developed; it is distinctly visible with the pocket-lens, but too small to be measured with certainty. It has the terminal pyramids partly developed at the other end also, and imperfectly showing the rare faces. It is intergrown with a left-handed crystal which on the face preserved exhibits the faces $s\ (2\bar{1}\bar{1}1)$, $x\ (6\bar{1}\bar{5}1)$ and $\Gamma\ (40\bar{4}1)$.

Twinning is common and, so far as observed, is always according to the Dauphiné law. The upper part of the crystal shown in fig. 3 is such a twin, of two right-handed individuals very perfectly joined, the twinning plane but faintly shown by cloudy patches within the crystal.

Fig. 1 is a twin of two left-handed individuals, the plane of twinning being well marked on the surface by a discontinuity in the prismatic striations, and by a plane of dark patches

* Sincere appreciation is expressed to Dr. M. Murgoci of Vienna for assistance in the measurement of the inter-facial angles, and to Dr. J. P. Smith of Stanford University for advice and aid in the preparation of this article.

within. This twinning is also markedly shown at the junction of the prism and pyramid faces, by the development on one individual of the e $(50\bar{5}1)$ face and on the other of the Γ $(40\bar{4}1)$ face. This twin has developed on one member between the m and z faces the x $(6\bar{1}\bar{5}1)$, Γ $(40\bar{4}1)$ and e $(50\bar{5}1)$ faces, and between m and r on the adjacent edge to the right, the x $(6\bar{1}\bar{5}1)$



Group of quartz crystals from Pala and Rincon, San Diego County, California.

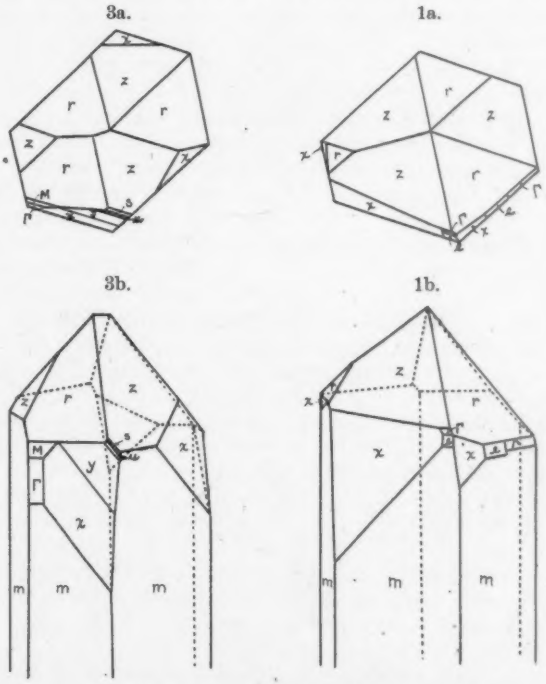
and e $(50\bar{5}1)$ faces; while the other member has developed only the $\Gamma(40\bar{4}1)$ face.

In figs. 3a, 3b and 1a, 1b are given orthographic and clinographic projections of the two crystals numbered 3 and 1 respectively in the group of crystals above, showing the relative size and positions of the rare faces.

Figs. 2 and 4 also are distinctly marked twins; the one shown by a joint or break along the prism face, the other by a distinct difference in opacity of the two members.

Deformation, or abnormal growth, is also met with. Fig. 6 is an example of parallel growth, while figs. 8, 9 and 10 are distorted forms. In fig. 10 the crystal is placed with its major axis perpendicular to the paper, so that one is looking down on the apex of the pyramid.

Corrosion or etching of the pyramidal faces, while those of the prism are unaffected, is illustrated in figs. 11 and 12.



Orthographic and clinographic projections of quartz crystals from Rincon, California, from figs. 3 and 1, p. 126.

One other extremely interesting point is that of the evidence of secondary crystallization, as shown by the filling up of the *x*, *y*, and *e*-$\bar{M}$ faces to a level, or nearly so, with the prism face. This is well exhibited in figs. 5 and 10.

While the *s* face occurs rather commonly elsewhere, the *x* and *y* faces are of much rarer occurrence. It is therefore worthy of note that upon the crystals of this region it is the trapezohedral faces that develop most frequently, while the *s* face, the trigonal pyramid, is seldom found.

Stanford University, California.

ART. XVII.—*On the Radio-active Properties of the Waters of the Springs on the Hot Springs Reservation, Hot Springs, Ark.;* by BERTRAM B. BOLTWOOD.*

THE Hot Springs Reservation is situated in Garland County, Ark., on the western slope of the Hot Springs Mountain, a spur of the Ozark Range. On the grounds of the Reservation the thermal waters rise through over fifty separate sources, and the total flow is estimated to be over 800,000 gallons in twenty-four hours.

During the summer of 1904, at the direction of the Secretary of the Interior, a thorough examination of the waters of these springs for radio-active properties was carried out by the writer. Samples of the waters were collected at the springs, some in July by Dr. Joseph H. Pratt, and the remainder in August by Mr. Martin A. Eisele, Superintendent of the Reservation. The samples were taken directly from the springs and were immediately introduced into large, glass receptacles. These receptacles were tightly corked and the corks were covered with a heavy coating of hot sealing-wax, thus hermetically sealing up the sample contained within them. The samples were shipped by express to New Haven, Conn., where the tests described in this paper were conducted. The samples were collected and shipped in separate lots of six each, and the tests were carried out as soon after the receipt of the samples as possible. The average time required for the transportation of the samples by the express companies was about seven days.

The constituents tested for were radio-active gas (emanation) and radio-active solids. An examination was also made of the tufa deposited by certain of the springs in order to determine whether this contained any radio-active substances.

The methods employed in the determination of the radio-active gas contained in the water, and in the determination of the presence of radium salts in solution, have already been described† in an earlier paper. The plan there followed of expressing the activity of the dissolved radium emanation in terms of the uranium equivalent has been modified to the extent of introducing a correction for the proportion of radium emanation lost by the pulverized sample of uranium mineral used for determining the standard.‡ Since the quantity of

* Published with the permission of the Secretary of the Interior.

† This Journal, xviii, 378, 1904.

‡ A method for determining the proportion of emanation which spontaneously escapes from the cold, finely-ground mineral has been described in the Phil. Mag. (6), ix, 599.

radium associated with a definite weight of uranium in a radio-active mineral has been shown* to be a perfectly definite and unvarying quantity, this method of expressing the activity of a given quantity of emanation affords a convenient and accurate standard for the comparison of samples of water from different sources.

Samples of water from forty-four of the different hot springs were examined. The properties of the gaseous, radio-active constituent were found to be identical with those of the radium emanation. The activity of the gas fell to one-half value in about 3·9 days and the active deposit, after two hours from the start, had a half-value period of twenty-eight minutes.

In the following table are given the quantitative results of the examination of the waters. The first column gives the laboratory number of the sample, the second column contains the number representing the activity of the gas actually obtained from one liter of water expressed in terms of the uranium standard,† the third column gives the number of days which transpired from the time of collecting the sample to the time of testing the water, and the fourth column gives the initial activity of the water (per liter) as calculated from the equation: $I_0 = Ie^{-\lambda t}$.

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
22A	0·9	8	3·7
23A	3·8	7	14·4
24A	1·8	7	6·8
25A	3·9	7	15·1
26A	8·4	7	31·9
27A	0·4	8	1·6
29A	6·3	7	23·9
30A	12·5	7	49·0
32A	7·6	7	28·9
33A	3·1	7	11·8
34A	7·7	7	29·3
35A	17·2	7	65·4
36A	14·4	7	54·7
37A	2·1	9	10·3
38A	0·9	7	3·4
39A	8·5	9	41·6
40A	2·6	10	15·3
41A	1·3	10	7·7
43A	1·3	7	4·9

* Boltwood, this Journal, xviii, 97; Phil. Mag. (6), ix, 599.

† The number denotes the weight in grams of the quantity of uranium in a radio-active mineral which is associated with a quantity of radium, the total emanation from which would be equivalent to the emanation obtained from one liter of the water.

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
44A	5·8	7	22·0
45A	0·9	9	4·4
46A	1·8	9	8·8
47A	8·1	6	23·5
48A	1·3	7	4·9
50B	1·7	9	8·3
51B	1·3	8	5·3
52B	0·17	6	0·5
54B	0·4	7	1·5
55B	2·1	7	8·0
56B	0·2	8	0·8
59B	3·4	7	12·9
60B	1·8	7	6·8
61B	4·9	6	14·2
62B	3·9	7	14·8
63B	25·6	7	97·3
64C	9 0	6	26·1
65C	5·0	6	14·5
66C	10·5	6	30·5
67C	2·5	8	10·2
68C	9·0	6	26·1
69C	13·8	6	40·0
70C	91·6	6	265·6
71C	3·6	7	13·7
72C	3·9	7	14·8

Radio-activity of Water on Standing.

A sample of water No. 39A was sealed up in a large receptacle holding about twelve liters and allowed to stand undisturbed for thirty-two days. At the end of this period the activity of the gases contained in the water was tested. The activity was very low and was not greater than the natural residuum which would remain from the emanation originally present. This indicated that the water contained no radium salts in solution.

A quantity of water No. 70C, from which the gas had been removed by boiling after acidifying with acetic acid, was allowed to stand in an open vessel for two days, and was then sealed up for twelve days longer. At the end of this time it was tested for radio-active gases, but no radio-activity could be detected in the gas which was obtained during the second boiling operation. This also indicated the absence of radium salts in solution.

Residues from Water.

About twenty liters of water from sources No. 39A and 67C were evaporated to dryness and the residue tested in the elec-

troscope. No indication of any activity in the solid substance could be obtained. The mineral salts in the residue were converted into chlorides, dissolved in water, and the resulting solution was sealed up for thirty days. The accumulated gases were boiled off and tested. The observed radio-activity was too slight to measure with any accuracy, and corresponded at most to the smallest detectable trace of radium salts in the waters.

Tufa from Springs.

On issuing from the ground a number of the springs form a deposit of "tufa," consisting chiefly of carbonate of calcium. A sample of this material weighing 100 grams was dissolved in dilute hydrochloric acid and the gas evolved was conducted into a strong solution of sodium hydroxide. A small residue of gases not absorbed by the sodium hydroxide solution was examined in the electroscope. The radio-activity of these gases indicated that the quantity of radium present in the tufa was less than one-millionth of the quantity of radium associated with an equal weight (100 grams) of uranium in pitchblende.

Gas from Springs.

Samples of the gases which rise with two of the springs were tested under conditions identical with those under which the gas obtained on boiling the water was tested. The measurements were carried out eight days after the gases had been collected at the springs, and the activity of the gases was found to be less than that of equal volumes of gases obtained by boiling the waters from the same springs.

Water from Cold Springs.

In addition to the hot springs, there are on the grounds of the Reservation two cold springs, situated on the northern slope of Hot Springs Mountain, and issuing from the earth about 800 feet from the nearest hot spring. An examination of the waters of these springs gave the following results:

Laboratory number.	Observed activity per liter water $g \times 10^{-4}$ uranium.	Days from time of collection.	Calculated initial activity.
73D	6·0	6	17·4
74D	18·1	10	106·8

Discussion of Results.

One of the most interesting results of the present investigation is the demonstration of such marked variations in the activity of the water from such a closely related series of springs. The temperature of the different springs varies from

35° C. to 64° C. and the total solids in the waters vary from 170 to 310 parts per million,* while the average amount of solids in all the springs is between 275 parts and 280 parts. In only a few of the springs do the solids fall below 270 parts or rise above 290 parts per million.

In their general chemical characteristic the waters from the different springs show a marked resemblance to one another, and such a great variation in the activity of the different waters was entirely unexpected. It will be noticed that the most active spring water (No. 70C) is over 500 times more active than the least active (No. 52B).

That these variations were in no way due to the conditions under which the particular samples were collected and tested was shown by the fact that duplicate samples collected at different times and by different persons gave closely agreeing results.

All of the hot springs are situated on a narrow strip of land about 500 yards in length. No connection can be discovered between the location of the springs and their radio-active properties. The more active springs are widely scattered and adjacent springs usually show great differences in the radio-active properties of their waters. As a general summary it can be stated that it has been found impossible to establish any connection between the temperature, flow, location or chemical composition of the waters of the springs and the observed differences in the radio-active properties.

Another interesting point is brought out by the relatively high activity of the two cold springs as compared with the least active hot springs. It will be noted that the second most radio-active water was that from the cold spring No. 74D. This would seem to indicate that the thermal qualities of the waters and their radio-active properties are due to quite independent causes.

The results of this investigation demonstrate the necessity of the quantitative examination of the water from each separate spring in order to obtain a definite knowledge of the radio-active properties of the waters derived from a number of adjacent, individual sources.

139 Orange St., New Haven, Conn., June, 1905.

* A very complete chemical examination of the waters of these springs has been made by Mr. J. K. Haywood of the U. S. Department of Agriculture. The results have been published under the title of "The Hot Springs of Arkansas," Senate Document No. 282, Government Printing Office, Washington, 1902.

Art. XVIII.—*On the Genesis of Riebeckite and Riebeckite Rocks;** by G. M. Murgoci, Bucharest.

Recent investigations have shown that riebeckite rocks are not uncommon; new occurrences are being discovered, and in old localities alkali rocks described as containing black or blue hornblende are often identified as really containing riebeckite. These rocks are attracting special attention, because of the presence of this rare sodium-iron amphibole, and because some of them are the most acid of alkali rocks, rising to 78 per cent in SiO_2 (according to the analyses of Butureanu, Ludwig, etc.) and to 10 per cent in Na_2O and K_2O.

I have discovered these interesting rocks in Dobrogea at Jacobdeal and Piatra rosie† (at the mouths of the Danube), and was able to study *in situ* their geological characters and relations to the enclosing rocks. I have also compared them in the laboratory with similar rocks from other localities. A résumé of the facts in Dobrogea is as follows:

In the Paleozoic formations composed of quartzites, sandstones and conglomerates, calcareous and argillaceous shales and crystalline limestone, the following rocks are found as intrusive masses: various kinds of granites, microgranites, quartz and orthoclase porphyries, diorites and olivine gabbros, etc., which in general occupy the anticlines of the sedimentary formations. All the foregoing rocks and the Triassic sandstone and limestone are penetrated by dikes of microgranites, porphyries, diorites, pearl and porphyritic diabases, etc. It has been proved satisfactorily that there have been two epochs of volcanic activity: Paleozoic (pre-Permian) and Triassic. Sometimes the mesocratic rocks of the two series are very similar and could easily be confused one with another, if the field relations are not correctly interpreted.

The rocks of the first volcanic epoch, usually alkali rocks (Mrazec), show a consanguinity obvious in the field and confirmed by investigation in the laboratory, Dobrogea being in this respect a very interesting petrographical province. Riebeckite rocks, however, are confined to the hills of the western Dobrogea in two of the anticlines of the slightly metamorphosed argillaceous shales and sandstones. The anticlines have a northwest-southeast strike and in the region of Carjelari run

* Preliminary communication read before the Geological Society in Philadelphia, December, 1904.

† G. M. Murgoci, Ridicări geologice in N. Dobrogei, Bull. Soc. Ingineriloc de mine, 1898, Bucuresti.

Among the specimens that I collected in the quarries of Jacobdeal, Prof. L. Mrazec recognized riebeckite granite and described it in: Note preliminaire sur un granite à riebeckite and aegirine des environs de Turcoaia (Dobrogea). Ibidem. 1899.

together, forming, by their uniting cores, one single large mass of eruptive rocks.* In this zone, granites (soda-granites, nordmarkite, and quartz syenite) microgranites and granite porphyries (granophyre and paisanite) and typical quartz and orthoclase porphyries are found together in the same or neighboring localities. One may remark, according to the present exposures and topography of these rocks, that the porphyritic masses, with or without riebeckite, occupy a larger area at the surface than the granite (in the proportion of 3:1); the region is much eroded, the layers are almost vertical and the porphyritic facies occurs in the western part of the granite zone. In this case the porphyritic rocks can not be regarded only as marginal facies of the granite massif. On the other hand, the various rocks with riebeckite form large streaks and patches (*schlieren*) mixed at random in the massives, with similar masses without riebeckite, but very acid and poor in black constituents. Some masses, especially those of more basic character, were obviously homogeneous and polygeneous inclusions. Although there are many quarries in the two hills of Jacobdeal and Piatra rosie, which furnish exposures, dike rocks of pegmatitic, aplitic or lamprophyric characters could not be found. In one place a rock of the type of nordmarkite occurs in such a manner that it might be regarded as a dike terminating abruptly upwards; the same rock, however, occurs in the neighborhood as polygeneous inclusions.

Owing to the absence of obvious dikes, it is impossible to determine the order of the ascension and consolidation of the magmas forming these various rocks. Their occurrence and structure, their study by chemical and petrographical methods and the relations between them, reveal to us only local phenomena which occurred during the consolidation of the large molten mass.

It is well known what a tendency the alkali magmas have to differentiate and especially in massives of sodic rocks; this fact can be very well confirmed, as shown by numerous researches. This phenomenon, often described in the alkali rocks of the trachyte-syenite series (especially in nephelite syenites), is also mentioned in massives with riebeckite rocks of the granite-rhyolite series, when studied over large areas. There might be cited the classic researches by Brögger (Christiania region), Tenne (Yemen), Washington (Essex County, Mass.†), Lacroix

* See the geological map by R. Pascu, Moniteur du Petrole roum. 1904. Bucharest.

† In the neighborhood of Boston, "the glaucophane granite" studied by White has been determined by Washington as riebeckite granite (Journal of Geology, vol. vi, No. 8 and foi., 1898–1899), and among the specimens which I possess through the kindness of Prof. Kemp, I was able to distinguish riebeckite granophyre, paisanite, interesting inclusions, etc. Even White described gradual variations of structure and composition in one and the same massif. Proc. of the Boston Soc. of Nat. Hist., 28, No. 6, 1897.

(Madagascar, Corsica, Colorado), Pelikan (Socotra, etc.), Harker (I. of Skye, etc.), and many interesting remarks in Rosenbusch's writings, where he discusses amphibole and pyroxene granites, etc. The very interesting example is given by Lacroix* in the rhyolite of Somalis, where schlieren of microgranite were observed in the rhyolitic mass.

I have recently compared my riebeckite rocks with those from Scotland, Wales and Massachusetts, and have been able to extend and generalize the conclusions of Lacroix† deduced from observations on different granites with riebeckite and ægirite, and I would include also microgranitic and porphyritic types from granite and quartz syenite series. Summarizing the observations, we may emphasize the characters which reveal to us the genesis of the riebeckite rocks as follows:

1. The massives with riebeckite rocks are characterized by a great variety of types rich in soda as schlieren or as dikes. In such massives there is very frequently a tendency towards a pegmatitic or miarolitic structure in some of the schlieren, and a fluidal or microgranitic one in others. Schlieren with a protoclastic structure may be observed in the holocrystalline types and also in porphyritic ones.

2. Variations occur not only in the structure, but also much more in the constituents, especially in the dark-colored ones, which are, however, almost always amphibole, or pyroxene, or both, often grown together or zonal. The amphibole in the most acid rocks is of the arfvedsonite-riebeckite group, in the relatively basic ones it is of the kataforite-barkevikite group; the pyroxene is ægirite or ægirite-augite. Ægirite nearly always accompanies riebeckite; but while ægirite occurs often as well developed, more or less idiomorphic, crystals, the large patches of riebeckite have, as is well known, a spongy, poikilitic structure with a well marked allotriomorphic development. The character of its occurrence, in even granular rocks and in porphyries, shows that riebeckite has been formed continually during the whole time of the consolidation of the magma. It is found as microlites, in small and minute prisms and needles or fibers, included in other constituents such as feldspar, quartz, etc.; as large dark-blue crystals grown together with other minerals, such as ægirite, zircon, and pyrochlore; as patches cementing feldspar and even quartz; as poikilitic shreds and beads in the groundmass of the porphyritic rocks; further it is found in miarolitic cavities, in pneumatogeneous inclusions, in the cracks and druses of the rocks filled by pegmatitic masses, etc.

* A. Lacroix, Les Rhyolites à aegirine and riebeckite de Somalis. C. R., Ac. Sc. Paris, cxxviii, 1899.

† A. Lacroix, Materiaux pour la Minéralogie de Madagascar. Nouvelles Archives du Muséum d'Hist. Natur. IV^e^ s. 1902, p. 164, etc. See also Les travaux de M. A. Lacroix, 1903.

3. The riebeckite rocks represent in the massives the pegmatitic varieties, consolidated under special physical conditions, riebeckite being a mineral which requires pneumatolitic conditions for its formation. All petrologists, who have studied riebeckite rocks, mention pegmatitic, micropegmatitic or granophyric structures as being characteristic of them. Brögger* has remarked that riebeckite (and arfvedsonite) occurs especially in rocks rich in quartz (over 60 per cent, according to the analyses of Butureanu† and E. Ludwig‡, up to 78·5 per cent), and on the other hand, while ægirite occurs in almost all the rocks of the Christiania region, riebeckite appears only in those which indicate high pressure, and is wanting in those pegmatitic dikes, where ægerite is the most frequent mineral. Flink & Böggild§ have described riebeckite ("type II of arfvedsonite," Riebeckite?) in the pegmatitic schlieren of Greenland (Narsarsuk), which are also very rich in ægirite. It must be noted, that the syenite pegmatites of Narsarsuk occur not as veins or dikes, like those from Christiania, but "there are dike-like syenite formations, which differ from the ordinary typical syenite, in having as chief elements constituents, rich in iron, of the pyroxene and amphibole series. There can be no question of dikes or deposits, ... the minerals show that the pegmatitic formations have arisen simultaneously with the bulk of the rock." Heddle, Prior, König, etc., have also studied perfect crystals from quartz dikes or miarolite cavities only. On the other hand, Lacroix‖ has described very characteristic pegmatites, containing the only large crystals of riebeckite known, which come from Colorado (San Petro's Dom), Corsica, Madagascar, etc. The riebeckite crystals occur in the pegmatite-like black tourmaline in common pegmatites; the riebeckite pegmatites pass over gradually into granitic or microgranitic rocks.

* W. C. Brögger, Eruptivgesteine der Kristiania Gebietes, i, 1894, pp. 36, 39, 184, 186, etc.

† V. Butureanu, Sur la composition des granite à Riebeckite de Jacobdeal, Dobrogea. Annales scientifiques de l'Université de Jassy, 1893. An analysis of riebeckite too.

‡ A. Pelikan, Petrographische Untersuchungen von Gesteine der Inseln Sokotra, Abdel Kûri und Semba. Denkschriften der Math. Naturw. Klasse der k. Akademie Wien, 1902, lxxi. Analyses by Prof. E. Ludwig.

§ J. Flink, O. Böggild and Chr. Winter. Untersuchungen über Mineralien von Julianehaab. Meddelelser om Groenland, 1899, 24. Reference in Zeitschr. f. Kryst. and Min. xxxiv, 1901.—N. v. Ussing (ibidem, 1894, Abstract in Neues Jahrbuch f. Miner., etc., 1901, 45) cites riebeckite also in syenite.

‖ A. Lacroix, after the communications to Academie de Sciences, Paris (Colorado, Comptes Rendus cix, 1889, Mt. Saber, C. R. cxxviii, 1899) returns to the Corsican rocks (described first by Le Vevier, C. R. cix, 1899, and Nentien, Mem. carte géol. France, 1897) in Minéralogie de la France. i, 695, and recently discusses the general question in Materiaux pour la Minéralogie de Madagascar. Nouv. Archives du Muséum d'Hist. Natur. 1902–1903. See also: Les travaux de M. A. Lacroix, 1903.

4. I may further emphasize the similarity of riebeckite, in its occurrence and petrographic characters, with the tourmaline from tourmaline granites, aplites, etc. The poikilitic structure of the large crystals, hypidiomorphic and allotriomorphic forms in one and the same rock, are characters common to both riebeckite and tourmaline. The rocks with tourmaline are very alkalic like those with riebeckite*; riebeckite like tourmaline eliminates other black constituents such as biotite. The riebeckite rocks have their special accessory mineral, zircon, in the same way that tourmaline rocks carry cassiterite.†

5. The quartz and the feldspars (which are orthoclase either with patches of soda-microcline or with albite in microperthite intergrowths, all more or less idiomorphic) contain many inclusions of riebeckite, zircon, and liquids with bubbles and cubes of common salt.

6. A great deal of zircon accompanies the riebeckite; Brögger, Washington, Mrazec, Lacroix and Souza Brandão (1905) emphasize this fact. Lacroix found as much as 7·5 per cent zircon in the rocks of Madagascar. The barkevikite rocks, on the other hand, contain much titanite. It is worthy of mention in this connection that Brögger‡ states that in the middle of a dike of quartz-lindöite (of west Aker, Christiania) riebeckite occurs with much zircon, crystallized after riebeckite, whilst at the salband there is katoforite and ægirite without zircon; on the other hand, zircon is very frequent in the pegmatitic dikes at the Christiania region. Zircon and titanite have been formed during the whole time of the consolidation of the magma-like riebeckite.

7. In miarolitic cavities of these rocks fluorspar, galena, zircon (spinel?) and riebeckite have been found together. Brögger, Lacroix and Washington state that fluorspar is often a constituent of the rocks rich in soda, which contain ægirite and riebeckite, and in general I have also found it in many of the rocks of the region studied by me and in those of other places, such as in the Quincy granite, the trachyte of Berkum near Remagen, the microgranite of Ailsa Craig, etc.

The occurrence of fluorspar in certain granites is very important from a theoretical standpoint; in them fluorspar occurs as small crystals, often microlites, grown together with or included in the ægirite; riebeckite when inter-grown with ægirite is quite free from such fluorspar inclusions, but may contain small pockets of rare carbonates (parisite?). In general

* The complicated composition of riebeckite is well known. I know of six analyses and no two alike; the differences can not come from mistakes only. On the other hand, riebeckite contains Fl also.

† A. Lacroix, Materiaux de Madagascar, loc. cit., i, p. 89.

‡ W. C. Brögger, loc. cit., pp. 137, 138.

ægirite granite carries much fluorspar; in the pure riebeckite granite, on the other hand, it is almost entirely wanting. Brögger* mentions the occurrence of much fluorspar and ægirite on the salbands of the grorudites of Omholtsaeter, which are apophyses of the soda-granite of Kongsberg and in relation with the genuine pegmatitic dikes and akmite granite of Rundemyr. According to Rosenbusch† in this massif there occurs also riebeckite granite.

Brögger‡ described also a peripheral transformation of barkevikite into ægirite and lepidomelane with a rich accompaniment of fluorspar, and he explains this change as due to pneumatolitic action at the end of the consolidation of the hydato-pyrogeneous mass or immediately after it. This may be possible in the pegmatitic dikes of Christiania, where Brögger has proved four phases of pneumatolitic action, ægirite being formed in the third phase. If the rock contains both riebeckite and ægirite, often grown together with fluorspars and carbonates, I believe the process to have occurred in another manner, riebeckite and ægirite being primary, fluorspar and carbonates also. It is well known what complicated relations of zonal and other intergrowths there are between the pyroxenes and amphiboles when they occur together, especially in ægirite-riebeckite rocks; some petrologists have considered the ægirite as a transformation product of riebeckite, and others have taken the riebeckite for a secondary product of ægirite. Among other examples there might be mentioned the one furnished by Cross§ in his description of amphiboles from Silver Cliff, Col., and another by Böggild (loc. cit.), who has found in the pegmatitic schlieren of Narsarsuk arfvedsonite covered by secondary ægirite, and in the same rock riebeckite with a core of ægirite. Most petrologists state, however, that riebeckite and ægirite are primary in their rocks. Without denying the later transformation of riebeckite into ægirite, a fact easy to imagine considering that their composition is similar and that ægirite seems to be the more stable form, I believe, however, that in general riebeckite and ægirite are both primary in rocks, and if transformations have taken place, they must have occurred before the consolidation of the magma.

The genesis at the same time of these two minerals of almost identical composition is a very interesting phenomenon and deserves to be taken for a moment into consideration: Steen-

* W. C. Brögger, ibidem, p. 190.

† H. Rosenbusch, Massige Gesteine, II ed., p. 59.

‡ W. C. Brögger, Die Mineralien der Syenit-pegmatitgänge von Norvegien. Zeitschrift der Krystallographie und Mineralogie, 16, 1890. The first part is devoted to the rocks of that region.

§ Whitman Cross, Note on some secondary minerals of the amphibole and pyroxene groups. This Journal, xxxix, 1890.

strup* by melting arfvedsonite has obtained ægirite; Doelter by melting gastaldite in sodium fluoride has also obtained ægirite or akmite, but without fluoride there resulted an amorphous mass. These two experiments and many others have shown that ægirite and pyroxene can originate in molten masses under ordinary conditions. This is, however, not the case with amphiboles, and recently Vogt† has demonstrated again that amphiboles require high pressure for their formation. Considering the facts more closely, for a medium to be capable of giving rise to the riebeckite or ægirite molecule (which may be expressed by $Si_8O_{16}Fe'''_2Fe''Na_2$‡), there appear to be two chief factors necessary, namely *pressure and mineralizers*§. The obvious fact that these two minerals can originate at the same time in a magna, shows that there cannot be much difference between their coefficients of solubility, i. e., their capacity for forming saturated solutions in the molten mass; on the other hand, the melting point of these minerals (aeg.=940°, rieb.=945° C. according to Doelter) is not different under ordinary circumstances and cannot vary much if the circumstances vary in the same way for both minerals. The structure of the riebeckite-ægirite rocks and the mode of occurrence of these minerals support the statement of Höpfner verified by Vogt (l. c.), that pressure has not much influence on the order of separation of the minerals in a magma and on the composition of eutectic mixtures. I may add, with respect to the ideas of Loewinson-Lessing,‖ that pressure alone is not sufficient to force a dimorphous substance to crystallize in one form rather than in another, although one may have a smaller true molecular volume than the other. According to this general dynamic rule, ægirite, with the smaller molecular volume, should be the characteristic mineral of the abyssal rocks rich in soda. Observation and experiment contradict this: ægirite can form under ordinary pressure and occurs much more in hypabyssal and volcanic rocks than in abyssal ones; riebeckite has not been obtained at ordinary pressure, but it occurs in trachyte with fluorspar and in rhyolites, which clearly show evidences of a pneumatolytic process. On the

* The best argument for the primary existence of the ægirite is its occurrence, in the same rock, with little thin needles of riebeckite, which could not resist even the slowest and slightest action of transformation.

† T. H. Vogt, Die Silikatschmeltzlösungen. Mem. of the Acad. of Christiania, 1904.

‡ This formula given by König, and confirmed by Butureanu on the Dobrogean riebeckite, agrees very closely with the analyses of ægirite by Doelter.

§ This question in particular I intend to take up again, after some experiments, with more detail.

‖ F. Loewinson-Lessing, Studien über Eruptivgesteine. Memoires du Congrès Geol. de St. Petersburg, 1897, p. 325 f.

other hand, the schistose metamorphosed riebeckite rocks of Gloggnitz and Alter Padroso, etc., show no transformation in this respect, ægirite and riebeckite having the same character and both being primary, often grown together or zonal, as in the unpressed eruptive rocks. We are forced accordingly to invoke, besides the composition of the magma and the pressure, also that important agent, which has left its traces in the components of these rocks, the *mineralizers.**

If now, p represents the conditions of pressure, which may be unity, or one atmosphere, and m the mineralizers†, which may be much reduced, of a magma in which the whole substance $Si_8O_{12}Fe''_2Fe''Na_2$ may crystallize as ægirite, then P and M may be the conditions of minimal pressure and mineralizers in which the same substance may crystallize as riebeckite. One can imagine that between the points p, m and P, M there may be a large number of stages (P_x, M_y), where there can arise a variable percentage A of ægirite to R of riebeckite, more or less respectively, accordingly as a particular stage is nearer to the point p, m or P, M.‡ The variation of the medium μ (composition of magna + mineralizers) influences in large proportion the phenomena, and the representative curve of the phenomena $f(m, p)$ is displaced in plane, and for a definite value of μ we meet with a critical point for the formation of riebeckite; in a magma below this limit,—riebeckite can no longer form under any pressure by the given mineralizers. And according to these different conditions of a magma, pressure and mineralizers, there can originate in one and the same igneous mass and at the same time of consolidation rocks with riebeckite only, rocks with riebeckite and ægirite in all proportions, and those with ægirite alone.

In this way we can explain the relations which have been observed between riebeckite, ægirite and fluorspar. The min-

* F. Loewinson-Lessing in his interesting discussion (l. cit. p. 359) admits the necessity for pressure and an active gas (he means water) for the formation of amphiboles. The experiments which he has made by melting pyroxenes and amphiboles in an atmosphere of water vapour have not been successful in producing hornblende. It would be very interesting to know what would be the result of an experiment in a fluorine atmosphere under a high pressure! I may note that the only synthetic hornblende (with 2% Na_2O) was obtained by Chrustschoff (1891) in sealed tubes in the presence of water at high temperature.

† That is to say, the capability of the mineralizers for forming minerals.

‡ This question is a very complicated one and we do not know how many substances and how many phases there are at a given moment. We may, however, imagine the simplified case of n substances (magma, iron-sodium silicate and fluorine mineralizers) and $n+1$ phases (magmatic solution, riebeckite, ægirite and gas). The most analogous example is to be found in the crystallization of calcite and aragonite (or conchite) from a dilute solution at varying temperatures. See: Beiträge zur mineralogischen Kenntnis der Kalkausscheidung im Tierreich von Agnes Kelly. Jenäischen Zeitschrift für Naturwissenschaft, 1900.

eralizers have not a catalytic action only; it has been demonstrated several times that they have an active part in the consolidation of magmas and in the formation of minerals. Accordingly, in a magma of a definite composition containing mineralizers and under a sufficient pressure to give rise to riebeckite, a part of the mineralizers (Fl, Na, Ti, Zr, etc.) play an active rôle in the formation of the riebeckite, entering also into its composition.* Where there is low pressure and the mineralizers are not appropriate for the formation of riebeckite, ægirite is formed, and the mineralizers, which it does not require for its production, react on the magma and among themselves, giving rise to other characteristic minerals with the form and paragenesis which we have seen above.

8. The former presence of high pressure and abundant active mineralizers can be clearly deduced from the study of riebeckite rocks, as may be seen from the works of Brögger, Lacroix and others. Lacroix, in particular, concludes from the presence of fluorspar, galena, zircon, and the pseudomorphic changes and alterations undergone by riebeckite and ægirite, that emanations characterized by fluorine and zirconium were active at the moment of consolidation, and that in riebeckite rocks zirconium plays the part of tin in alkali rocks with tourmaline. He, like Brögger, assumes a powerful manifestation of post-volcanic activity, which in some cases has produced deposits of cryolite, as at St. Peter's Dome, Colo., and in Greenland, or marked transformations in the structure and composition of the rocks, as in the rhyolite of Somalis.

According to my researches in Dobrogea the post-volcanic activity is almost wanting in massives with many schlieren and much variation in the kinds of rocks. No pegmatitic dikes or veins like those in Greenland or Norway have been seen in the many quarries in Jacobdeal and Piatra rosie, and the contact metamorphism of the neighboring rocks is very small. I may add that, in this respect, the alkali granite of Măcin and Pricopanu shows much greater contact phenomena and pneumatolitic post-volcanic activity. In the cracks of the Jacobdeal granite I have found only a few spots coated with little crystals of quartz, hæmatite, very rarely fibers of crocidolite, and beautiful dendrites of ferromanganese hydroxides like those from the Quincy granite.

* This deduction finds a certain verification in the composition of riebeckite; unfortunately the existing analyses are very unsatisfactory. In a recent conversation with Dr. Tassin, he informed me that he had found fluorine in a riebeckite which he is analyzing. Amphiboles with fluorine are known; for example, see the pargasites, etc., in the table of analyses by Hintze, and the hornblende from Grenville (Quebec) with 2·8 per cent Fl (Harrington, B., this Journal, 1903, p. 392). Perhaps the loss in König's (riebeckite) analyses (made, he says, with all precautions) may be fluorine.

The pneumatolitic elements have been in the magma and reacting rather during the time of the consolidation of these riebeckite rocks than later (as I have attempted to show above). The study of the inclusions of riebeckite granite give further support for this statement. Such inclusions have been mentioned by Brögger, Washington, and White, but do not seem to have aroused much interest. I have found many inclusions in the granite of Jacobdeal and Piatra rosie, and have observed some in the Quincy granite. They may be classified as follows:

Homogeneous inclusions, that is aggregates of riebeckite which are often fibrous (crocidolite?), with spongy quartz, zircon and hematite; the riebeckite forms large prisms but is not well developed.

Pneumatogeneous inclusions, that is, those formed by mineralizing vapors which are porous or hollow, with a great deal of fluorspar, galena, pyrites, pyrotite, mispikel, hematite and many earthy looking minerals which are certainly alteration products of other minerals; riebeckite and augite-ægirite are rare, feldspar is more frequent and there is very little quartz.*

Polygenous and enalogenous inclusions formed by varying combinations of processes, of variable size and composition; in such inclusions occur large crystals of orthoclase and albite, pyroxenes, amphiboles (but no riebeckite), astrophillite, mica, etc. Through the assimilation of these inclusions local variations in the composition and structure of the granite arise, and rocks are formed (endopligenous inclusions) of the types of nordmarkite, akerite, grorudite, paisanite and even quartz-pulaskite and sölvsbergite. The occurrence of these different rocks as inclusions is very striking in the many quarries of Dobrogea and also in specimens from Quincy, Mass†. In many of these rocks riebeckite is replaced by katoforite or barkevikite, and this fact can be explained, in my belief, by variation in the composition of the magma under definite limits, while pressure and mineralizers remain the same as in the main mass.

Lacroix has described from Ampasibitika contact rocks of a riebeckite granite (perhaps in part inclusions) and states that they contain the same minerals, riebeckite—sometimes in pseudomorphic forms—ægirite, fluorspar, spinel and zircon, which occur in the granite. The contact of Dobrogea does not show marked metamorphism; there are epidote, pyroxene and amphibole hornfelses, but without riebeckite, and it may be

* G. Murgoci, Minerale din Dobrogea. Publicatiunile Soc. Naturalistilor, 2, 1902. Bucharest.

† I may further remark that the analyses of an enclosure in granite of Pigeon Hill, by Washington (loc. cit.), does not differ at all from the akerite analyzed by the same investigator. Journal of Geology, 1898-99.

added that in general this mineral does not occur in genuine schists. The well known forellengranulite (orthogneiss) of Gloggnitz,* the riebeckite granulite of Alter Pedroso in Portugal,† are surely eruptive rocks,‡ and their characters are quite similar to those summarized above. Lacroix§ mentions genuine schists with riebeckite from Corsica, from the Alps of Savoy, from Bulgar Dagh in the Taurus, etc., which occur associated with glaucophane schists. It is to be noted that the riebeckite of these rocks occurs as needles and fibers, radially spherulitic or lenticular, and it has always been compared with the tourmaline of luxullianite. In some rocks, especially holocrystalline ones, needles and fibers of riebeckite(?) are found in such relation to large crystals of riebeckite or ægirite, that they look like secondary products and are quite similar to those described by Cross, Lane, White and Washington. Cross has identified the blue amphibole of Silver Cliff with the crocidolite of Lacroix‖; perhaps it is the case that all these kinds of blue amphiboles should be referred to crocidolite.¶ Crocidolite seems to be different from riebeckite both in occurrence and composition; its genesis in riebeckite rocks seems to show that it should there be primary, indicating circumstances which Weinschenk presupposes in piezocrystallization; and many characters of crocidolite are in accordance with this hypothesis, as S. Franchi has deduced for the glaucophane (and crocidolite) schists.

From the above mentioned characters of riebeckite and of the rocks in which it occurs, we may, to some extent, deduce the circumstances under which these rocks have been formed, especially those from Dobrogea.

The magma which has given rise to the riebeckite rocks ascends from an alkaline magma basin, from which it is derived by a process of magmatic differentiation. The molten mass,

* H. Keyserling, Der Gloggnitzer Forellenstein: Tschermak's Mineral. petrogr. Mittheilungen, xxii, 1903.

† V. de Souza Brandão, Ueber einen portugesischen Alkaligranulit. Centralblatt für Mineralogie, Geologie und Paleontologie, 1902, p. 50.

‡ Dr. Teall and Fleet have found, last summer, in Wales, a riebeckite gneiss which in mineralogical and petrographical characters seems a granite gneiss.

§ A. Lacroix, Mineralogie de la France, i, p. 697.

‖ With the blue amphibole described by W. Cross, C. Palache has identified another blue amphibole, *crossite*, from an albite schist of Berkeley, Bul. of Geol. Depart. Calif. Univ., i, 1894. I may observe, however, following the comment of Lane and my own determinations, that this cannot be done; the crossite of Berkeley is a blue amphibole (glaucophane) which has the plane of the optic axes perpendicular to (010), $b:c=16°$. But I have found the amphibole of Cross in a syenite from Spanish Peak, Cal., and it looks like crocidolite.

¶ S. Franchi, Prof. Louderback, etc., have found crocidolite quartzite in the area of glaucophane schists which are very similar to the riebeckite schists described by Lacroix.

isolated perhaps in an anticline or in a laccolith, is maintained for a long time as a mother liquor in a state of hydrothermal fusion in which there swim crystals already formed, or in process of formation. On account of the impermeability to vapor of the beds of shale, quartzite, etc., between which it has been introduced, the mineralizers cannot escape, they continue to act on the magma and to be gradually assimilated. The presence of fluorspar, zircon, titanite, and sulphides as constituents of the riebeckite rocks, the occurrence of pneumatogeneous and polygeneous inclusions and of schlieren with characteristic minerals confirm this view.

The chief factors in the formation of riebeckite rocks are the pressure and definite mineralizers; with the variation of these two factors and of the composition of the magma, the products of crystallization are also changed. Only under high pressure due to tectonic movements and to the persistent retention of mineralizing vapors, and with a large quantity of the latter present, could riebeckite be formed; if one of these factors varied, especially the pressure, ægirite would then occur in addition to riebeckite. Of course the pressure, the mineralizers and the composition of the magma usually differ from one point to another, as may be seen from the quantitative and qualitative variation of the mineral elements of the rocks. Especially had the assimilation of inclusions of neighboring rocks provoked such variations of chemical and physical conditions, that riebeckite could no longer be formed.

In addition to the chemical, a mechanical action was present; new upwellings of fluid magma and of mineralizers cause streams and vortices in the consolidating molten mass. These influence the crystallization and aid in the formation of schlieren; in the more quiet parts a pegmatitic or a granular structure is produced; there in the streams and more agitated areas a fluidal or a protoclastic structure originates; the rapid sinking of the temperature, the loss of mineralizing vapors, or lowering of pressure in other parts, determines a porphyritic structure with the two periods of consolidation more or less well pronounced of the mineral constituents.*

Riebeckite forms only in the relatively most acid magmas, and especially under the influence of mineralizers: its composition, content of fluorine, long period of crystallization from the beginning up to the end of and even after the consolida-

* In respect to the conception of the rôle of the mineralizers and inclusions, their influence at the time of consolidation of the magma, the forming of schlieren and of the structure, I incline toward the views of the French petrologists. None the less, in the ideas of Prof. E. Weinschenk I have found many points à propos to these views; the short and clear chapters on these questions in his book, Gesteinskunde I, 1902, excite my heartiest admiration.

tion of the magmas; its occurrence in cavities and its paragenesis with zircon, pyrochlore, fluorspar, sulphides, etc.; its presence as large crystals in pegmatites in immediate relation with veins of fluorspar or cryolite, and its absence in non-eruptive rocks, are many facts which support the view as to its origin presented in this paper.

The mineralizers which aid to produce it are not rich in water and sulphur vapors, but are characterized by an abundance of Zr, which has played a part in riebeckite granite similar to that of Sn in cassiterite granites. Zircon also forms throughout the whole period of consolidation. One can correlate: tourmaline—Sn; riebeckite — Zr and katoforite (or another soda amphibole)—Ti.

The magma has been fairly rich in Al_2O_3, Na_2O, and K_2O, but a large quantity of soda and iron have been brought in by mineralizers and the genesis of riebeckite facilitated. The occurrence of masses and small areas of hæmatite and limonite, around or across the inclusions and schlieren, does not come from secondary alteration, but from areas which at the moment of consolidation were still more or less impregnated with iron compounds and water vapors.

Doubtless new upwellings of magma and of mineralizers have caused some transformations in the minerals already formed in the riebeckite and ægirite, but needles and fibers of crocidolite could be formed in eruptive rocks, as well as in metamorphic schists, as a phenomenon of piezocrystallization, which is quite in accord with the process which I have here tried to sketch.

Art. XIX.—*Purpurite, a new Mineral;** by L. C. Graton and W. T. Schaller.

Introduction.

In the central portion of the Carolinas there occurs a belt of metamorphic rocks penetrated by narrow dikes of pegmatite, many of which contain lithium minerals. There can be little question but that the dikes of pegmatite represent the final product of a parent magma which has crystallized as granite and appears almost continuously along the extent of this belt.

Attention was first directed to these pegmatites by the discovery of cassiterite in them. In the autumn of 1904, one of the writers made an examination of these tin deposits for the U. S. Geological Survey. During the course of this study, Mr. J. L. Daniels, superintendent of the Faires tin mine at Kings Mountain, Gaston County, N. C., called attention to a purplish material encountered within a few feet of the surface in the workings of that mine. Thanks are due to Mr. Daniels, who kindly supplied much of the material obtained. Preliminary examination failed to identify the material with any known mineral, although its properties seemed to be those of a definite crystalline compound. Chemical analysis shows that the material is a new mineral, being a hydrous manganic ferric phosphate—the only manganic phosphate known.

The most striking feature of this mineral is its purple or dark reddish color, and for this reason it has been named *purpurite*, from the Latin *purpura*, purple or dark red.

Since the discovery of this mineral in North Carolina, the same mineral has been noticed on some specimens from San Diego County, California, These had been collected by one of the writers, and through the courtesy of Mr. F. M. Sickler, of Pala, several more specimens from this locality have been obtained. They are from one of the lithium-bearing pegmatite dikes on Hiriart Hill, Pala, San Diego County. The mineral occurs with triphylite, and possesses the same purple color as the North Carolina specimens. Under the microscope, the appearance and properties of the mineral from the two localities are identical. There is, however, not enough of the California material for chemical examination.

Occurrence and Physical Properties; by L. C. Graton.

The mineral purpurite is found in small irregular masses in the tin-bearing pegmatite dikes, and in the near-by schist at the Faires mine. In most cases it occurs in narrow lenses or

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veinlets, and appears to have been deposited from solution in cavities. Occasionally, however, it is found in the midst of the pegmatite as if it were an original mineral.

The question of the origin of purpurite is one of interest. Pegmatite dikes believed to be closely related to the tin-bearing dikes carry the rare-earth phosphate, monazite. Among the primary minerals of the tin-bearing pegmatites are cassiterite, tourmaline, apatite, spodumene, lepidolite, and a yellowish brown, lithia-bearing phosphate which is doubtless lithiophilite. The last two minerals have been found only in small quantities. Partially decomposed specimens of this pegmatite frequently show much manganese dioxide as thin mammillary coating on the other minerals. Ilmenite is often included in crystals of cassiterite. It is evident, therefore, that the elements manganese and iron (as monoxides), lithium, and phosphorus (as phosphate) were primary components of the pegmatite magma.

The mineral presumed to be lithiophilite is always surrounded by a coating of black, secondary material. In one case, a narrow zone of purpurite was found between the lithiophilite and the black mineral. It is believed that this single occurrence furnishes the explanation of the origin of purpurite. A lithia-manganous-ferrous phosphate, probably lithiophilite, was attacked by oxidizing solutions. The lithia was almost wholly carried away, while of the remaining elements, iron and manganese were oxidized to the state of sesquioxides and were recrystallized with the phosphoric acid and water to form purpurite. The trace of lithium which this mineral contains is a remnant of that from the lithiophilite. In some cases the recrystallization took place without transportation of the materials, forming pseudomorphous replacements, but in general the materials were carried in solution to cavities and there deposited.

Purpurite is probably orthorhombic, but no specimens have been found which show crystal outline. A cleavage which is probably pinacoidal is of rather perfect development, but the cleavage surfaces are often curved as if the orientation of adjoining grains were not exactly the same. A second cleavage, presumably at right angles, is considerably less distinct. The mineral has an uneven fracture and is rather brittle. It is scratched without difficulty by the knife, but on the other hand just scratches fluorite, and hence has a hardness of 4–4·5. Mr. Schaller determined the specific gravity as approximately 3·15. In color the mineral is a rich deep red or reddish purple, sometimes with a slight bronzy iridescence, and not uncommonly darker on the cleavage planes. The powder and the streak have a decided purple or deep rose color. The mineral has a peculiar satiny luster or sheen, more noticeable on fracture surfaces than on cleavage planes.

Although transparent in very thin pieces, the ordinary thin section allows the passage of very little light through purpurite. The colors in transmitted light are very beautiful. Pleochroism is noticeable. Parallel to the cleavage the color is a deep scarlet, inclining to rose-red, while across the cleavage the absorption is greater and the color becomes a beautiful purple. This absorption, it will be noticed, is similar to that of tourmaline and a few other minerals, in which the greatest absorption is at right angles to the direction of cleavage or elongation. Extinction is generally parallel; an inclination up to three or four degrees, which has been observed in a few instances, has probably been due to the orientation of the sections examined. It may be, however, that the mineral is monoclinic, with a very small extinction angle. Sections which were transparent were not of sufficient size to give an interference figure. No sections showing the intersecting cleavages were seen, and in all the sections examined the traces of the cleavages are parallel to the direction of greater elasticity of the section; so if the mineral is biaxial, the intersection of the cleavages is parallel to a. This is also the direction of least absorption. The refractive index is somewhat greater than that of Canada balsam and probably lies between 1·60 and 1·65. The difference of the indices or the double refraction is high, and although it could not be measured at all accurately, is probably not much below ·060. One effect of this high double refraction on the very thin sections examined is that under crossed nicols the mineral appears to transmit as much and as brilliant light as without polarization. The red interference colors are very striking.

The purple mineral is always covered or surrounded by a greater or less thickness of a black or brownish black material of pitchy luster and uneven or sub-conchoidal fracture. This material, which is soluble in hydrochloric acid, has been found by Mr. Schaller to contain iron, manganese, phosphoric acid, and water. Under a lens the black material can be seen to encroach upon the purpurite, eating in along the cleavage planes and gradually replacing the purple mineral. It is undoubtedly a decomposition product of purpurite and is certainly the same as that which surrounds the supposed lithiophilite. Viewed with the aid of the microscope it appears to be a definite mineral, having an imperfect cleavage, and a brownish yellow color in transmitted light. Extinction is nearly or quite parallel to the cleavage, and the trace of the cleavage is the direction of least refractive index of the sections examined. Pleochroism is distinct and, as in the case with purpurite, absorption is greatest across the cleavage. The index of refraction is greater than that of Canada balsam, and the double refrac-

tion is probably rather high. It is hoped that sufficient of this material for analysis will soon be obtained.

The occurrence of purpurite in material collected from California by Mr. Schaller throws additional light on the origin and association of this mineral. It occurs with a black material which appears to be identical with that described above, and both are undoubtedly decomposition products of the accompanying triphylite, the iron-rich member of the lithia-manganous-ferrous phosphate series, of which lithiophilite is the manganese-rich end.

The small number and rarity of minerals containing manganic oxide, Mn_2O_3, may be due to the relative instability of that base in comparison with manganese dioxide.

Chemical Composition; WALDEMAR T. SCHALLER.

About a gram of pure material was separated by Mr. Graton. This was divided into several portions, using about a fifth of a gram for each determination. The most interesting part of the analysis was to determine the state of oxidation of the manganese. When the mineral is treated with hydrochloric acid, chlorine is readily given off. The manganese present can therefore not be in the manganous state, and the absence of ferrous iron and the presence of ferric iron suggested that the manganese was present as a manganic salt. Such was found to be the case.

A fifth of a gram was dissolved in sulphuric acid with a known amount of ferrous ammonium sulphate. All precautions were observed to avoid the presence of air, the entire operation being conducted in an atmosphere of carbon dioxide. The water used had been boiled and cooled out of contact with air. Just before the iron sulphate was introduced into the flask containing the mineral, an equal quantity was removed from the stock solution and titrated with permanganate. Thus, the amount of ferrous iron introduced into the flask with the mineral was known. After the mineral had been decomposed by the sulphuric acid, the flask was cooled and the solution titrated, the amount of iron sulphate oxidized by the liberation of oxygen from the mineral being determined in this way. From these data the amount of Mn_2O_3 was calculated and found to be 30·47 per cent.

A second sample was decomposed by hydrochloric acid and the chlorine evolved passed into a solution of potassium iodide. The liberated iodine was then titrated with sodium thiosulphate, the latter being standardized with pure copper. Calculating from the results obtained, the amount of Mn_2O_3 was found to be 27·93 per cent. Though these results vary somewhat, yet, considering the small amount of material used

(1/5 gram) and the many operations necessary, the agreement is as close as could be expected. The average of the two results is 29·20 per cent.

A direct determination of the total manganese, weighed as anhydrous sulphate, gave as the amount of Mn_2O_3 in the mineral, 29·35 per cent, which agrees almost exactly with the average of the two indirect determinations.

The remaining constituents were determined as follows: A portion of the mineral was dissolved in hydrochloric acid and a known weight of iron added (as ferric chloride). A basic acetate separation was then made, boiling the solution for fifteen minutes, which according to Bunsen will precipitate all the phosphoric acid with the iron and will not precipitate any manganese. The precipitate was dissolved in hydrochloric acid, and reprecipitated by ammonia, after the addition of some ammonium chloride. The two filtrates were united, manganese precipitated by hydrogen sulphide and finally weighed as anhydrous manganese sulphate. Calcium was then thrown out, dissolved and reprecipitated and magnesia found to be absent. The iron-phosphate precipitate was dissolved in hydrochloric acid and divided into two portions. In the one, the iron and phosphoric acid were precipitated by ammonia and weighed. This was then fused up with sodium bisulphate and tested for manganese with silver nitrate and ammonium persulphate. None was present. In the second portion, the iron was reduced by hydrogen sulphide and titrated with permanganate. Phosphoric acid was determined in the usual way and a second value obtained by the difference between the iron and the iron plus phosphoric acid. The alkalies were determined by the Lawrence Smith method. The final solution of chlorides gave a strong spectroscopic test for lithium. The water below 105° was determined directly, using a toluene bath. The total water was determined directly by heating in a glass tube according to Penfield. The water is all given off at a low temperature, that at 105° being given off very readily, and at one time. Further heating at 105° failed to remove any more. The values obtained are as follows:

		Av.	Ratio.	
Fe_2O_3	15·89,	15·89	1·03	2·96
Mn_2O_3	29·35, 30·47, 27·93	29·25	1·93	
P_2O_5	47·64, 46·96	47·30	3·47	
H_2O	5·26	5·26	3·04	
CaO	1·48	1·48	·27	·41
Na_2O	·84	·84	·14	
Li_2O	tr.	tr.		
Insol.	·52	·52		
		100·54		

The amount of water given off at 105° is 3·31 per cent. As all of the water is so readily given off, it is most probably present as water of crystallization.

Considering that the calcium and soda require some phosphoric acid, the ratio of $R'''_2O_3 : P_2O_5 : H_2O$ is approximately 3 : 3 : 3. Combining the ratio of the calcium and sodium with that of the iron and manganese, and reducing these to their hydrogen equivalent, the ratio becomes

$$H_{18\cdot88}P_{6\cdot94}O_{26\cdot64} + 3\cdot04H_2O$$

$$\text{or } 2[H_{2\cdot97}P_{\cdot93}O_{4\cdot04}] + \cdot92H_2O.$$

The acid is therefore H_3PO_4. The formula for the mineral then becomes $R'''_2O_3 . P_2O_5 + H_2O$.

It is not known in just what state of combination the calcium and sodium are. They most probably represent some slight impurity. If the manganic and ferric oxides are isomorphous in the sense that manganous and ferrous oxides are, the ratio of Mn_2O_3 to Fe_2O_3 being nearly 2 : 1 is of no significance and the formula then should not be written $Fe_2O_3 . 2Mn_2O_3 . 3P_2O_5 + 3H_2O$, but $(Mn''', Fe''')_2O_3 . P_2O_5 + H_2O$, the mineral purpurite being near the manganic end of an isomorphous series having as its two end members:

$$Fe_2O_3 . P_2O_5 + H_2O$$

$$Mn_2O_3 : P_2O_5 + H_2O.$$

There are only a few hydrous phosphates of the normal division in which the base is trivalent, such as scorodite and strengite. All of these, however, contain more water than the mineral here described.

While no manganic phosphates were noted in the literature, there are a number of arsenates containing Mn_2O_3, with none of which, however, can purpurite be classed. Synadelphite, flinkite, arseniopleite, and perhaps hematolite, contain Mn_2O_3 with Al_2O_3 or Fe_2O_3, while in durangite and arseniosiderite, Mn_2O_3 is reported in small amounts.

The mineral fuses easily and readily gives off water in a closed tube becoming yellowish brown. It is readily soluble to a clear solution in hydrochloric acid, while in nitric acid a black oxide of manganese separates out. The specific gravity determined on the powdered mineral by the Thoulet solution is approximately 3·15.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Studies with the Liquid Hydrogen and Air Calorimeters. I. Specific Heats;** by Sir James Dewar.—"The calorimeter employed in the following researches was similar to that described in my paper on 'The Scientific Uses of Liquid Air,'† and in an improved form in Madame Curie's work 'Recherches sur les Substances Radio-Actives,' 2d edition, p. 100. A sketch of the apparatus appears in my paper on 'The Absorption and Thermal Evolution of Gases Occluded in Charcoal at Low Temperatures.'‡

The arrangement employed consists essentially of a large vacuum vessel capable of holding 2 or 3 liters, into which is inserted a smaller vacuum vessel of 25 to 50 c.c. capacity constituting the calorimeter, the latter being sealed on to a long narrow tube which projects from the mouth of the exterior vessel, in which it is lightly held by a loose packing of cotton wool. A little below the upper end a branch tube is taken off which conveys the volatilized gas from the calorimeter to the gas receiver. To the extremity of the projecting tube a small test-tube, to hold the portions of substance experimented on, is attached by a short piece of rather wide rubber tubing which forms naturally a movable joint that can be bent into any position. With care I have found this valve gives as good results as more elaborate means of securing the dropping of the substances into the calorimeter. A small vacuum vessel containing solid carbonic acid, liquid ethylene, liquid air, etc., into which the test-tube is placed, cools the materials to different temperatures below those of the laboratory, or alternatively it may be heated in the vapour of water or other liquids."

The general constants for liquid gas calorimeters (here omitted) show that "an instrument in which liquid air is used has twice the sensibility of a corresponding one in which liquid ethylene is employed, whereas the substitution of liquid hydrogen for liquid air increases the delicacy of the calorimeter some seven times. It is easy to detect the tranference of 1/50 of a gram-calorie in the liquid air instrument, whilst 1/300 of a gram-calorie can be similarly observed in the liquid hydrogen form of the calorimeter."

A detailed account is given of the method of use of the instrument and also of the various sources of error. Of the experiments described the following results were obtained for carbon in the form of diamond and of graphite, and for ice.

* Extracts from an advanced proof (received from the author) of a paper read June 8, before the Royal Society of London.

† Proc. Roy. Inst., 1894, vol. xiv, p. 398.

‡ Proc. Roy. Soc., 1904, vol. lxxiv, p. 123.

Substance.	18° to −78°.	−78° to −188°.	188° to −252°·5.
Diamond	0·0794	0·0190	0·0043
Graphite	0·1341	0·0599	0·0133
Ice	0·463*	0·285	0·146

"It appears from these values that between the ordinary temperature and the boiling point of hydrogen the specific heat of the diamond has been reduced to 1/19, whereas under similar conditions graphite has diminished to about 1/10. Further it will be observed that at the lowest temperatures the specific heat of graphite is about three times that of the diamond. It is also worthy of being recorded that the values of the specific heats of diamond and graphite taken between the temperatures of liquid air and boiling hydrogen are far smaller than that of any known solid substance, being even lower than that of any gas taken under constant volume."

Another table gives the results obtained, at temperatures extending down to −188°, for the specific heats of various substance including German-silver, brass, tellurium, sulphur, etc., to solid carbon dioxide, solid ammonia and solid sulphur dioxide. The author concludes with the remark that "an almost endless field of research in the determination of specific heats is now opened, in which the use of liquid air and hydrogen calorimeters are certain to become ordinary laboratory instruments."

2. *On the Thermo-electric Junction as a Means of Determining the Lowest Temperatures;* by Sir JAMES DEWAR.†—"The inconvenience of using the gas thermometer at very low temperatures and the failure of platinum and other metal-resistance thermometers within 30° or 40° of the absolute zero, led me some years ago to consider the experimental behavior of the thermo-electric junction at the lowest temperatures. My special object at the time the experiments were made was to have a further confirmation of the melting point of hydrogen, and also of the lowest temperature reached on exhausting solid hydrogen, other than that I had found by means of the hydrogen gas thermometer.‡ The results have remained unpublished, because my intention has always been to extend them to other thermo-electric combinations. Not having been able to accomplish this project, they are now abstracted as affording useful information in this field of investigation, and as furnishing a general confirmation of my previous investigations.

A German-silver platinum couple was selected as likely to give the most uniform results at low temperatures, although subsequent experiments have led to the conclusion that it would have been better to have replaced the platinum by gold. As regards resistance thermometers, I have shown that gold is more reliable

* This from −18° to −78°.

† Extracts from an advance proof (received from the author) of a paper read June 8 before the Royal Society of London.

‡ The Boiling Point of Liquid Hydrogen, determined by Hydrogen and Helium Gas Thermometers, Proc. Roy. Soc., vol. lxxviii, 1901.

than platinum at temperatures near the boiling point of hydrogen.* The difficulties of the investigation were considerable: it had to be carried out at the time in the neighborhood of the machinery producing the liquefied gases required in the investigation, namely, oxygen, nitrogen, and hydrogen, so that the zero of the delicate galvanometer employed did not remain quite constant. To remedy this I inserted a rocking make-and-break in order to get the readings of each observation at both ends of the scale. In the process of removing one difficulty another presented itself, through the development of small but appreciable thermo-electric currents in the rocker. Precautions had to be taken against these and at all other metal junctions against similar small thermo-electric currents, and it was even found necessary to have a correction on account of the resistance box, inserted in the circuit to bring large readings within the limits of the scale. The galvanometer and resistance box were inserted in the German-silver branch of the couple, the points of junction of the copper leads with the German silver ends of the couple being insulated and placed close together within a vacuum test-tube packed with cotton wool to ensure equality of temperature.

Preliminary experiments showed that the junctions altered after having been subjected to the temperature of liquid hydrogen. However, on re-soldering the junctions with hard silver solder instead of soft solder, the thermo-couple accurately repeated observations at the temperature of liquid oxygen, after having passed through a liquid hydrogen bath. From this it appears that all such couples before calibration ought to be cooled suddenly in liquid air and then rapidly heated to the ordinary temperature, a similar operation being repeated with liquid hydrogen. If the couples return to their original state after such abrupt changes of temperature, then they are in a fit state for calibration.

Three series of observations were made to determine whether the resistance of the junctions varied to a noticeable extent with the temperature, namely, at the freezing point of water, at the boiling point of oxygen, and at the boiling point of hydrogen. Six very concurrent observations with varying resistances in the resistance box were made between 0° C. and 15° C. These were reduced by the method of least squares, and gave for the resistance of the circuit 3·500 ohms. Five similar results between the melting point of nitrogen and the boiling point of oxygen gave, by least squares, 3·293 ohms. Only two observations were taken in liquid hydrogen, which are therefore not entitled to the same weight as those already given, but the resistance appeared again about 3·3 ohms. As the variation of the resistance of the circuit was so slight, an attempt was made to reduce the results on the assumption of constancy, but this was not satisfactory. However, on treating the variation of the resistance of the circuit as linear with the temperature, the data came into better agreement.

* Bakerian Lecture, "The Nadir of Temperature and Allied Problems," Proc. Roy. Soc., vol. lxviii, 1901.

The following table contains the details of the observations made with the silver soldered German-silver platinum couple, the recorded readings of the galvanometer being the means of several observed readings, corrected when necessary for resistance introduced into the circuit :—

No. of expt.	Substances used for difference of temperature.	Corresponding absolute temperatures.	Mean absolute temperature.	Mean galvanometer reading.	dE/dt.
1	Water of 15° and ice	280°, 273°	280½°	463·2	30·88
2	Boiling carbonic acid and ethylene.....	195, 170	182½	693·5	27·74
3	Boiling ethylene at 10^{mm} and oxygen..	123½, 90½	107	724·0	21·94
4	Boiling oxygen and nitrogen	90½, 77½	84	279·0	21·46
5	Boiling nitrogen and melting nitrogen..	77½, 62½	70	320·7	21·38
6	Boiling hydrogen and melting nitrogen..	62½, 20½	41½	623·5	14·84
7	Boiling hydrogen and melting hydrogen.	20½, ?	?	51·0	?
8	Boiling hydrogen—solid hydrogen about 20^{mm}.....	20½, ?	?	64·0	?

where dE/dt is the quotient of the mean galvanometer reading by the difference of the temperatures in the third column.

On plotting the first six of these results the 1st, 2d, and 6th and means of the other three, viz., $dE/dt = 21{\cdot}59$ at $t = 87°$, lie nearly on a continuous curve. The continuity of the curve, without any approach to abrupt change of form, even in the region of liquid hydrogen, shows that a silver-soldered German-silver platinum couple is an efficient instrument for the determination of the lowest temperatures hitherto reached."

A detailed discussion of the four sets of observations, Nos. 3, 4, 5, 6, follows, with the results given below ; those from Nos. 5 and 6 are probably the most accurate.

"The general results with the German-silver platinum junction may be summarized in the following table, the typical equation being $dE/dt = m + nT$.

Source of constants.	m	n	Melting point of hydrogen.	Solid hydrogen exhausted.
(3) and (6)	12·52	0·108	16°·4	15°·27
(4) and (6)	11·49	0·158	15°·9	14°·7
(5) and (6)	9·931	0·231	15°·0	13°·5
Graphically.....	10·2	0·167	15°·5	14°·15
Mean.....	....	....	15°·7	14°·4

It is added that in the paper on liquid hydrogen, already referred to, the temperatures obtained by the hydrogen gas thermometer for the boiling point of hydrogen and the solid under exhaustion were 19°·63 and 14°·34 respectively. Finally it is concluded that, "at as low a temperature as 6° absolute, the sensibility of this couple is still half what it was at 20½° absolute, and therefore that, unless some absolute breakdown in the law connecting electromotive force and temperature below 14° takes place, it must continue to be an excellent thermometer, and will record temperrature with considerable accuracy down to the boiling point of helium, which is about 5° or 6° degrees absolute."

II. Geology.

1. *Geology of the Vicinity of Little Falls, Herkimer County;* by H P. Cushing. Bull. 77, New York State Mus., 1905, pp. 95, pls. 1–15, and topographic and geologic maps.—Mr. Cushing here gives an account of the geology of one of the most interesting regions in New York. In this presentation he does not limit himself to the area of his map, but notes as well the general geology of the Adirondack region, thus setting forth in a philosophical manner the historical events which have taken place in northeastern New York.

The author states that the Adirondacks formed a low-lying land when the Potsdam sea encroached upon it. "It is possible that a small area may have persisted above sea level throughout [to the close of Utica time], though it is not likely, and in any case it was very small." The southern part of the Adirondack mass was the last to pass beneath the sea. The Potsdam is thickest on the northeast border, thinning out both westward and southward; it is not known on the south side about Little Falls. Upon the Potsdam along the eastern side was laid the Beekmantown limestone, but, according to the reviewer, it is questionable whether the so-called Beekmantown of the southern exposure is of the same age. These southern dolomites are 450 feet thick at Little Falls, but diminish to "nearly or quite zero at the northern limit of the sheet." Upon this formation in both areas follow the limestones of the Mohawkian series and then the Utica shales. At the top of the Utica "the present Adirondack region was either wholly submerged or else so nearly so that only a few small islands were left protruding above the water." This is not the generally accepted view and the occurrence of Potsdam within the Adirondack mass will have to be explained as depressed fault-blocks.

"Following the deposition of the Utica formation came a movement of disturbance and uplift of the region on the northeast and east. This apparently raised the present Champlain valley and northern Adirondack region above sea level, while the southern portion was not affected and remained submerged. . . .

"Quite possibly the first faulting of the region took place at the close of the Lower Silurian coincidently with the Taconic

disturbance. . . . The Little Falls fault has a throw of nearly or quite 800 feet at Little Falls."

One of the most interesting problems suggested by this bulletin is—What is the relation of the so-called Beekmantown formation of this Little Falls region to the true Beekmantown of the Champlain valley? The author shows how these dolomites overlap and disappear northward over the Adirondack mass. "Nor does the basal bed at Little Falls appear to represent the real base of the formation, deep well records to the west seeming to indicate an increased thickness in that direction." The sequence of the Upper Cambrian and the succeeding dolomites of the Great Interior Sea apparently denote continuous deposition and show that the dolomites along the south side of the Adirondacks are those of a shallow sea, with a sparing fauna. Their age is probably closely connected with the Cambrian and is doubtless older than the Beekmantown of the Lake Champlain area. The faunas of the two areas are widely different, that of the Lake Champlain district being a normal marine one abounding in large cephalopods and gastropods, hardly any of which are found in the Mohawk valley. Again, the sequence varies greatly in the two areas, as in the Lake Champlain region the Beekmantown is followed by the Chazy, while in the Mohawk valley the Lowville reposes on the so-called Beekmantown dolomites. On the northeast side of the Adirondacks the Paleozoic section is at least 3000 feet thicker than in the Mohawk valley.

C. S.

2. *Geology of the Watkins and Elmira Quadrangles, accompanied by a geologic map;* by JOHN M. CLARKE and D. DANA LUTHER. Bull. 81, New York State Mus., 1905, pp. 1–29, with a map and a section.—This Bulletin describes in detail the Upper Devonian strata of these quadrangles, with considerable notation of the occurrence of the faunules of the following horizons:

			Feet.
Neodevonian	Chatauquan	Chemung sandstone and shale	800
		Prattsburg shale	250
	Senecan	High Point sandstone	85
		West Hill flags and shale	315
		Grimes sandstone	75
		Hatch shale and flags	440
		Rhinestreet black shale	1
		Parrish limestone, in the Cashaqua shale	207
		West River shale	35
		Genundewa limestone	1
		Genesee shale	6+

Much detail is presented in regard to the distribution of the characteristic Naples or black shale fauna and its interlocking but rarely commingling with the eastern or Ithaca fauna. The latter is a direct outgrowth of the Hamilton, as may be seen from

Bulletin 82, reviewed below. The eastern or Ithaca fauna appears for the first time, but sparingly, in the lower portion of the Cashaqua shale, as far west as the region about Watkins Glen, and there are several alternations of this fauna with the Naples in the higher Hatch shale. The Iowa Lime creek fauna of 32 species has its only occurrence near the middle of the High Point sandstone, while *Spirifer disjunctus*, apparently a migrant also from the west or southwest, is seen for the first time in the Genesee valley, in the lower portion of the Prattsburg shale. "The horizon of *Spirifer disjunctus* follows close on the change from the Naples fauna in western New York at a high altitude above the base of the Portage formation. In central New York there is no such change, but the gradation from the Ithaca fauna out of the Hamilton fauna upward into the association which carries species elsewhere concurrent with *Sp. disjunctus* is very easy, and it is extermely difficult to draw a division plane anywhere except on the basis of refined distinctions into successive faunules. *Spirifer disjunctus* in this eastern region did not appear till this period of 'Chemung' deposition was well nigh over." C. S.

3. *Geologic Map of the Tully Quadrangle;* by JOHN M. CLARKE and D. DANA LUTHER. Bull. 82, New York State Mus., 1905, pp. 35–70, with map.—This Bulletin describes the following formations:—

				Feet.
Neodevonian	Senecan	Ithaca	Ithaca flags and sandstones	450
		Portage	Sherburne flags	210
		Genesee	Genesee shale	75
		Tully	Tully limestone	23
Mesodevonian	Erian	Hamilton	Moscow shale	180
			Ludlowville shale	350
			Skaneateles shale	335
		Marcellus	Cardiff shale	175
			Marcellus shale	100
	Ulsterian	Onondaga	Onondaga limestone	65
Paleodevonian	Oriskanian	Oriskany	Oriskany quartzite	6
	Helderbergian	Helderberg	New Scotland limestone and Coeymans limestone	40
Silurian	Cayugan	Manlius	Manlius limestone	74
			Rondout dolomite	40
			Cobleskill dolomite	6
		Salina	Bertie dolomite	15
			Camillus shale	40

The evidence regarding the presence of the New Scotland in this area is not convincing. As the present writer did not find this formation to the east, about Litchfield, it appears to him more probable that the New Scotland does not occur in the Tully quadrangle.

Dr. Clark adds a chapter on the "Ithaca fauna of Central New York," and lists 199 species collected by Mr. Luther from 80 stations. Of these forms, not less than 106 occur beneath the top of the Tully, abundantly confirming the statement of the author that "the fauna in point of number is prevailingly affiliated to that of the Hamilton."

The leading Hamilton species commonly found at these stations are the following: *Phacops rana, Pleurotomaria sulcomarginata, Actinopteria boydi, Glyptodesma erectum, Modiomorpha concentrica, M. mytiloides, Grammysia bisulcata, Cimitaria recurva, Microdon bellistriatus, Nuculites oblongatus, Nucula bellistriata, Palæoneilo emarginata, Paracyclas lirata, Rhipidomella vanuxemi, Spirifer mucronatus, Cyrtina hamiltonensis, Camarotœchia congregata* and *Tropidoleptus carinatus.* C. S.

4. *Contribution to the Paleontology of the Martinez group;* by CHARLES E. WEAVER. Univ. California Pub., Bull. Dept. Geol., pp. 101–123, pls. 12, 13, date of printing not given.—This Eocene fauna consists of 67 species. Of these 18 are new and with 3 others are described and illustrated.

"The Martinez represents a distinct division of time in the geological history of California. It contains a fauna distinct from both the Chico and the Tejon. On the average it is composed of about two thousand feet of thick-bedded sandstones, together with some shales, thin-bedded sandstones and conglomerates. . . . Its position in the geological scale seems to correspond most closely to a portion or all of the lower quarter of the Eocene."

"There was probably no direct faunal connection between India and the Western Coast of North America in Martinez times. . . . The evidence seems also to point to the fact that during this period the Martinez seas were isolated from the regions of the southeastern United States." C. S.

5. *Faune cambrienne du Haut-Alemtejo (Portugal);* par J. F. NERY DELGADO. Comm. Serv. Geol. du Portugal, v, 1904, pp. 307–374, pls. 1–6.—This work describes a very interesting Lower Cambrian fauna. It is especially noteworthy because of an abundance of bivalve shells of which 9 species are described, whereas in North America the Olenellus fauna is known to have but 2 species and but one of these is common.

The author regards this fauna as probably Lower Cambrian; from a survey of the genera adopted, however, his readers would be perplexed to know to what age these beds should be referred, were it not for the good photographic plates illustrating the species. *Paradoxides choffati* is clearly an Olenellus. The several species (9) of Hicksia are very suggestive of Lower Cambrian Solenopleura and especially of a form found at York, Penn. Of Microdiscus, the author describes 5, but *M. caudatus, M. subcaudatus,* and *M. wenceslasi* must be placed under a new genus, because they have dorsal eyes and a caudal spine. As *M. souzai* and *M. woodwardi* have eyes, they, too, should be referred to

another genus. It may be best to erect a new genus with *M. woodwardi* as the genoholotype, and a new subgenus with *M. caudatus* as the type species.

The Pelecypoda, as far as their generic reference is concerned, are very inadequately treated. One is referred to Posidonomya ?, 2 to Modiolopsis, 1 to Synek ?, 3 to Davidia, and 1 to Ctenodonta. While these names may indicate the types of pelecypods represented, yet it is safe to state that a careful study will show that all belong to other, probably new genera. The species are small and thin-shelled. In a conversation with Professor Verrill he concluded that all these Lower Cambrian bivalves were probably free-swimming forms.

The brachiopods are also very unsatisfactorily referred generically, and the illustrations are inadequate for more accurate determination.

This fauna of Portugal is certainly of Lower Cambrian age, and while it has relationship with that of York, Penn., yet in its trilobites and especially in its pelecypods it has a faunal facies entirely distinct from any American Lower Cambrian fauna.

C. S.

6. *Paraphorhynchus, a new genus of Kinderhook Brachiopoda;* by STUART WELLER. Trans. Acad. Sci. St. Louis, XV, 1905, pp. 259–264, pl. 1.—This rhynchonelloid form has the interior generic characters of Camarotœchia, with the exterior of Pugnax, to which is added a finely striated surface of the shell. The genoholotype is *Paraphorhynchus elongatum*, sp. nov. Other species are *P. transversum*, sp. nov., *Rhynchonella striatocostata* Meek and Worthen, *R. medialis* Simpson, and *R. striata* Simpson.

C. S.

7. *Sympterura Minveri, n. g. et sp.: a Devonian Ophiurid from Cornwall;* by F. A. BATHER. Geol. Mag., II, 1905, pp. 161–169, pl. 6.—This important paper describes in detail the skeleton of this brittle-star. The description is followed by a learned interpretation of the parts of the organism and their relation to other ophiurid structures. C. S.

8. *The ancestral origin of the North American Unionidæ, or fresh-water Mussels;* by CHARLES A. WHITE. Smithsonian Misc. Coll. (Quarterly Issue), June, 1905, pp. 75–88, pls. 26–31.—After a long silence in Paleontology, Dr. White returns to a group of shells on which he has often worked.

The oldest American Unionidæ occur in the Triassic. They "are all of simple form, and none of them exhibits distinctive prototypal relationship to the living Mississippi River fauna." Of Jurassic species, but seven are known and none of these appears to be directly related to the living shells. Toward the close of the Cretaceous, "the family received an extraordinary development" and increased its diversity. In the Laramie strata are found the greatest number of species of *Unio* having prototypal features connecting them with existing species in so marked a manner "that Professor Whitfield has given names to

the fossil forms [three] which are only modifications of the names of the living forms which they so closely resemble." In the Tertiary all connecting forms are absent, but the author explains that the Cenozoic species thus far found are plain types such as are now obtained only in still waters or lakes. "The more diverse and ornamental forms of living Uniones occupy fluviatile, or other running or moving waters. None of the deposits containing the Tertiary Uniones referred to gives any inherent evidence of having been formed in fluviatile or estuarine waters."

"Fresh-water gill-bearing faunas have as certainly descended genetically through successive geological ages to the present time as have marine faunas. . . . There has never been any intermission of such continuity because the fresh-water supply has never failed, and because, as a rule, rivers have been among the most persistent of the earth's surface features." C. S.

9. *The Thalattosauria, a group of marine reptiles from the Triassic of California;* by JOHN C. MERRIAM. Mem. California Acad. Sci., V, 1905, pp. 1–52, pls. 1–8.—During the past three years the Geological Department of the University of California has been collecting the remains of the marine reptiles from the Upper Triassic of Shasta county. From the fact that both are black, the material is very difficult to clear from the matrix, the latter being a shaly limestone.

This memoir describes in detail the skeletal structure of the Thalattosauridæ, comprising the genera *Thalattosaurus* (*T. alexandræ, T. shastensis* sp. nov., *T. perrini* sp. nov.) and *Nectosaurus* gen. nov. (*N. halius* sp. nov.). The pen and ink illustrations are good.

"The Thalattosaurs represent an early adaptation to marine conditions of that division of the Reptilia which has persisted in measurably primitive form in the Rhynchocephalia. During the early history of that group it gave rise to a numerous company of forms taking quite divergent paths in their evolution. Of the older orders only the Proganosauria were aquatic. They appear, however, to have been limited to fresh water. The Thalattosaurs are evidently the marine representatives of this great rhynchocephalian or diaptosaurian group." C. S.

10. *The Geology of Littleton, New Hampshire;* by C. H. HITCHCOCK. Pp. 38, 2 plates and map. Reprinted from History of Littleton, 1905.—This paper brings together all that is known in regard to the geology about Littleton, including the recently published article by Hitchcock (Bulletin Geol. Soc. America). The strata present are referred to the Quaternary, Helderberg, Silurian, Lower Silurian or Cambrian, and eruptives. In an appendix, Mr. Avery E. Lambert describes a new trilobite, *Dalmanites lunatus*, with notes on other fossils from the Littleton area. C. S.

11. *Vorschule der Geologie;* von JOHANNES WALTHER. Pp. 144, and 98 original text figures. Jena, 1905.—This very interestingly written, simply stated, and well printed little book on elementary geology is intended for beginners in geology. They

are led to observe nature for themselves and are shown how to determine the stratigraphic sequence in the profiles leading up to map making. Comparative stratigraphy and historical geology are not here considered.

There are 18 chapters, as follows: 1. Introduction; 2. Geological exposures; 3. Weathering (physical, chemical, and organic); 4. Results of weathering; 5. Kinds of rocks; 6. Rock-clefts or joints; 7. Subterranean waters and springs; 8. Infiltration of joints and caves; 9. Flowing waters; 10. Standing waters; 11. Sea-shore; 12. Mountains and hills; 13. Deformation and earthquakes; 14. Plutonic appearances; 15. Volcanic activity; 16. Stratigraphic sequence; 17. Maps; 18. Chronological sequence.

The book is distinguished for two things: The "Aufgaben" and the many clear and well-drawn diagrams of geological structures. At the end of each chapter, under "Aufgaben," the student is directed how and where to look for the things described. There are 110 of these lessons. C. S.

12. *Die Moore der Schweiz mit Berücksichtigung der gesammten Moorfrage;* von Dr. J. Früh und Dr. C. Schröter. Herausgegeben von der geologischen Kommission der Schweiz-Naturforschenden Gesellschaft. Preisschrift der Stiftung Schnyder von Wartensee. Pp. 751, 5 plates, figures in text. Bern, 1904.—This voluminous quarto report comprises a most elaborate treatment of swamps and peat-bogs, particularly in regard to those of Switzerland. Dr. Früh, professor of geography, and Dr. Schröter, professor of botany, at the Polytechnikum at Zurich, have combined in a most thorough manner the knowledge concerning these deposits from the point of view of geography, climatology, and botany. The first part of the work deals with vegetal deposits now making in northwestern and central Europe and in a general way with those of other districts, with reference to the classification of the deposits and an analysis of all the conditions which affect the growth of the plants and the accumulation of vegetal deposits. The second part of the work is devoted to a detailed description of local deposits within the confines of Switzerland. Throughout this work the botanist and the geographer have labored together to present precisely and technically the varied conditions which are displayed in the various plant colonies encountered within their field of study. Over 6,000 microscopic preparations were examined in the study of the stratigraphy of peat-beds. Helpful schematic tables arranged in the form of geological cross-sections of the types of swamp accumulations present a summary of the chapters of description, in which climate, altitude, position in relation to sunshine, slope, drainage, and accidental factors, are equally faithfully portrayed with encyclopedic fulness. A useful discussion of the world distribution of vegetal accumulations of the present day is accompanied by a mercator's chart showing the grouping of the broader divisions of vegetal deposits. There is also a chapter on the flora of the interglacial deposits. The authors, notably Früh, do not find that bacteria are effective producers of the change from

ordinary cellulose to the peaty state of vegetable matter. As a contribution to the æcology of plants the work is of exceptional interest. To the student of Pleistocene and Post-glacial deposits it seems clear that a like investigation of the vegetal deposits of America, for which there is abundant material, would prove equally valuable. There is an appended bibliography of 280 or more papers, and a topographic map of Switzerland on the scale of 1 : 530,000 showing by colors the distribution of swamps.

J. B. W.

13. *A Study of Recent Earthquakes;* by CHARLES DAVISON, Sc.D., F.G.S. Pp. xii + 355, with 80 illustrations. London, 1905 (Contemporary Science Series. The Walter Scott Publishing Co.).—The scope and object of this work are well stated in the opening paragraph of the preface, here quoted :

"The present volume differs from a text-book of seismology in giving brief, though detailed, accounts of individual earthquakes rather than a discussion of the phenomena and distribution of earthquakes in general. At the close of his *Les Tremblements de Terre,* Professor Fouqué has devoted a few chapters to some of the principal earthquakes between 1854 and 1887; and there are also the well known chapters in Lyell's *Principles of Geology,* dealing with earthquakes of a still earlier date. With these exceptions there is no other work covering the same ground; and he who wishes to study any particular earthquake can only do so by reading long reports or series of papers written perhaps in several different languages. The object of this volume is to save him this trouble, and to present to him the facts that seem most worthy of his attention."

The eight earthquakes selected are those which have been most thoroughly studied, "or which are of special interest owing to the unusual character of their phenomena, or the light cast by them on the nature and origin of earthquakes in general."

This volume is a welcome addition to recent earthquake literature, and forms what may be regarded as a valuable supplementary volume to the recent work of Dutton's treating of earthquakes in general.

J. B.

14. *An Introduction to the Geology of Cape Colony ;* by A. W. ROGERS, Director of the Geological Survey of Cape Colony. With a chapter on the fossil reptiles of the Karroo Formation by Prof. R. BROOM, M.D., BSc., of Victoria College, Stellenbosch. 463 pp., 21 plates, 22 text figures and a colored geological map. London, 1905. (Longmans, Green & Co.)—This well written and clearly printed book makes a very desirable addition to geological literature, bringing into one compact volume the geology of Cape Colony and enabling the specialist in other geological fields to gain, with a minimum of effort, a comprehensive idea of this distant part of the earth.

The Cape System is the oldest within which organic remains have been found, the middle member consisting of shales and thin sandstones 2500 feet thick containing fossils identical with or closely related to species which are found in Devonian rocks

of America and Europe. Beneath the Cape System are found a great thickness of closely folded and metamorphosed sedimentary formations largely injected with granite and embracing as many as four unconformable subdivisions.

The base of the Cape System consists of the topographically prominent Table Mountain sandstone, with a maximum thickness of 5000 feet, remarkably constant in character over the whole area of its present occurrence, probably over 90,000 square miles, pointing to its deposition over a wide shallow platform with unknown limits fronting a land which probably lay to the northward. An interesting feature is the occurrence of a thick shale-band with pebbles up to five inches in diameter occasionally flattened and striated. The pebbles are scattered irregularly through the shale and mudstone without any tendency to form beds of conglomerate. Considering all the evidence, it is concluded that the pebbles were distributed by floating ice somewhere early in Neopaleozoic times.

Following the Cape System, conformably in the south but unconformably in the northern portion of the Colony, is the Karroo System, with a maximum thickness of not less than 14,000 feet; it is rich in the remains of Permo-Carboniferous and Triassic reptiles. Its base, the Dwyka Conglomerate, a thousand feet in thickness, appears to consist in the south of iceberg deposits and in the north of true bowlder clay resting unconformably upon striated and moutonnéed surfaces with indications of ice movement from the north toward the south. Several plates from photographs illustrative of these highly interesting occurrences are given.*

Sometime after the middle of the Karroo a period of folding set in, building the mountain structures of Cape Colony facing outwards toward the oceans. This was followed by a period of great basic intrusions and of volcanism closing the Triassic. Since that time the history of Cape Colony has been preëminently one of successive uplifts and erosion; an erosion history interrupted in early Cretaceous times by a partial subsidence and probably an increased aridity of climate, and checked occasionally in later times by an approach of the river valleys to base level.

It is to be noted that on the southeast the even coast line cuts across the folded structures for a distance of four hundred miles, and there are indications, as in a downfaulted remnant of the Cretaceous, that post-Cretaceous faulting has played an important part in this truncation of older structures and the present termination, at this place, of the continental platform. J. B.

15. *Ice Erosion Theory a Fallacy;* by H. L. FAIRCHILD. Bull. Geol. Soc. Amer., vol. xvi, pp. 13–74, pls. 12–23. Published Feb., 1905. Read Jan. 1st and Dec. 30th, 1904.—In this article the author defines glacial erosion as the power of making vast and deep excavations in the solid or live rock, resulting in

* See also the article on this subject by E. T. Mellor in this number, pp. 107–118.

the excavation of fiords and large lake basins, a power which is questioned by many geologists and accepted by others equally, if not more, numerous; the capacity of removing loose material and of plucking away frost-loosened blocks, especially where facilitated by vertical jointing, being, on the other hand, universally conceded.

The arguments for deep erosion are discussed in detail and are considered to be inconclusive. Following this, concrete illustrations are given from several glaciated mountain ranges, showing a scouring and polishing action in valleys originating from preglacial erosion rather than a topographic transformation of the preglacial surface.

Among the important consequences from such conclusions, Fairchild considers that fiords and hanging valleys may and ordinarily do occur as the result of preglacial erosion, masked, however, by the glacial occupancy and signifying therefore certain preglacial changes in the altitude of the land. It is conceded, however, that glacial action emphasizes and makes more conspicuous hanging valleys of preglacial origin.

Following the above is a discussion of the evidence from the state of New York, with the conclusion that continental as well as Alpine glaciation is ineffective as a powerful erosive agent.

In many ways the quantitative value of ice erosion is an important problem and the writer has certainly presented ably his views upon the subject, but they would probably have met with a readier acceptance among those holding different opinions if prefaced with a less assertive and combative title. Many details of the argument, such as the significance of cross striae as indicative of weak erosive power, are still open to discussion in a manner similar to that on the subject of hanging valleys; but coming down to the essential conclusions of the problem, Professor Fairchild and many of his opponents upon this question are probably nearer together than would at first appear, the problem turning on the quantitative value of ice erosion: the one side holding that it is rapid and important, the other that it is slow and very subordinate to the aggregate effects of the previous fluvial and subaërial sculpture.

J. B.

16. *Hanging Valleys;* by I. C. Russell. Bull. Geol. Soc. Amer., vol. xvi, pp. 75–90. Read Dec. 30th, 1904. Published Feb., 1905.—A number of prominent physiographers have considered hanging valleys to result as a rule from the unequal erosion of valleys by glaciers of unequal size and to represent therefore the differential erosive power of the main and tributary glaciers, the total erosive power being necessarily still greater.

Dismissing the idea of glacial action as being the sole or necessary cause, a hanging valley may be defined, as stated by Chamberlin and Salisbury, as "when the lower end of the tributary valley is distinctly above the level of its main." On this basis Russell divides hanging valleys into four species, namely, stream-formed, ocean-formed, diastrophic, and glacier-formed. Even

among the glacier-formed "there appear to be at least six sets of conditions or processes each of which may produce glaciated hanging valleys without necessitating a conspicuously great measure of differential ice erosion." Illustrations confirmatory of these conclusions are cited from Stein mountain in southeastern Oregon and from the Sierras.

The discussions of this paper may be considered as an amplification of one phase of the general problem presented in Fairchild's paper, and tending likewise to diminish the conception of the total magnitude of ice erosion. J. B.

17. *Glaciation of the Green Mountains;* by C. H. HITCHCOCK, LL.D., pp. 21. Montpelier, Vt. (Argus and Patriot Press, 1904.)—After a review of the literature and an examination of the data in regard to all the higher summits of New England and New York, Dr. Hitchcock concludes that all, including Mt. Katahdin, Mt. Washington and Mt. Marcy, were completely buried beneath the continental ice and that any nunataks must be sought for among the Catskills or some other highland comparatively near the ice-border just as they are in Greenland to-day. J. B.

18. *Ice or Water;* by SIR HENRY H. HOWORTH. In three volumes. London, 1905 (Longmans, Green & Co.).—This voluminous work, each volume consisting of some five hundred pages, is by the author of a previous work of the same character entitled "The Glacial Nightmare and the Flood." He calls the present volumes "Another appeal to induction from the scholastic methods of modern geology," and reiterates and amplifies the views current in regard to the origin of the "drift or diluvium" previous to 1840.

For geologists there is no need of a review of this work as the titles of this and the previous one are sufficiently explanatory, but as the former has met with some little acceptance among those interested in geology but not specialists in the science, as is witnessed in a recent work by the Rev. N. Hutchinson, and as this is doubtless intended for the same class of readers, it may be well to say that the conclusions drawn in these volumes are essentially those held previous to 1840, thoroughly threshed out during the next twenty years and as thoroughly abandoned by all active geologists for the past thirty. A considerable part of the argument turns upon the idea that since the *causes* of the ice age are but poorly understood and there is as yet no unanimity of opinion upon that subject, therefore it is bad logic to believe in the existence of an age of ice at all.

The author has, however, read up glacial literature with considerable thoroughness, and he destroys to his satisfaction every theory of the glacialists including those which are founded upon the best accepted facts as well as those proposed upon insufficient knowledge and which have been already left by the wayside by all prominent glacialists themselves. In reading these volumes one is reminded of a criticism of Brögger dealing with a similar reversion to an earlier period of thought "Der menschliche Geist

ist wunderbar conservativ: denn Ansichten, die man schon längst als todt und begraben ansehen müsste, stehen immerfort wieder als Gespenster aus der Vergangenheit auf." J. B.

III. Miscellaneous Scientific Intelligence.

1. *The United States National Museum;* by Richard Rathbun. Report of the U. S. National Museum for 1903, pp. 177–309, with 29 plates. Washington, 1905.—This is a very readable and well illustrated account of the Government Museum buildings in Washington; the first of these is the picturesque Smithsonian building finally completed in 1855 and restored in 1865–1867 after the partial destruction by fire in January, 1865. This was followed by the National Museum, completed in 1881 under Secretary Baird. The plans for the new Museum building, the foundations of which have been recently begun, are also presented.

2. *Forestry: Tenth Annual Report of the Chief Fire Warden of Minnesota*, for the year 1904; by C. C. Andrews. 135 pp., with 17 plates.—The annual appropriation by the State of Minnesota in behalf of the preservation of its forests amounts to the very small sum of $5,000. The present report shows how much can be accomplished with even this amount, and it cannot be believed that the strong plea of the Chief Fire Warden for adequate support and an enlightened policy can be disregarded; certainly the matter is one in which the State has a vital interest.

3. *Les Prix Nobel en 1902.* Stockholm, 1905.—The Swedish Academy of Sciences has recently distributed an interesting volume giving an account of the distribution of the Nobel prizes in 1902, with plates showing the medals and diplomas, also the portraits of the recipients accompanied by brief biographies. The prizes were awarded as follows, viz.: in physics, to H. A. Lorentz and Pieter Zeeman; in chemistry, Emil Fischer; in medicine, Ronald Ross; in literature, Theodor Mommsen. The volume also contains the Nobel lectures by Professors Lorentz, Zeeman, Fischer, Ross and Ducommun.

4. *Negritos of Zambales;* by William Allen Reed. 90 pp., 62 plates. Manila, 1904 (Ethnological Survey Publications, vol. II, Part 1).—Of the various publications which appear from time to time from Manila, not the least important are those devoted to ethnological subjects. The present paper, which forms Part I of vol. II, is devoted to an account of the interesting race of pygmy blacks, the Negritos of Zambales Province; it presents the subject very fully, with a large number of plates, reproduced from photographs.

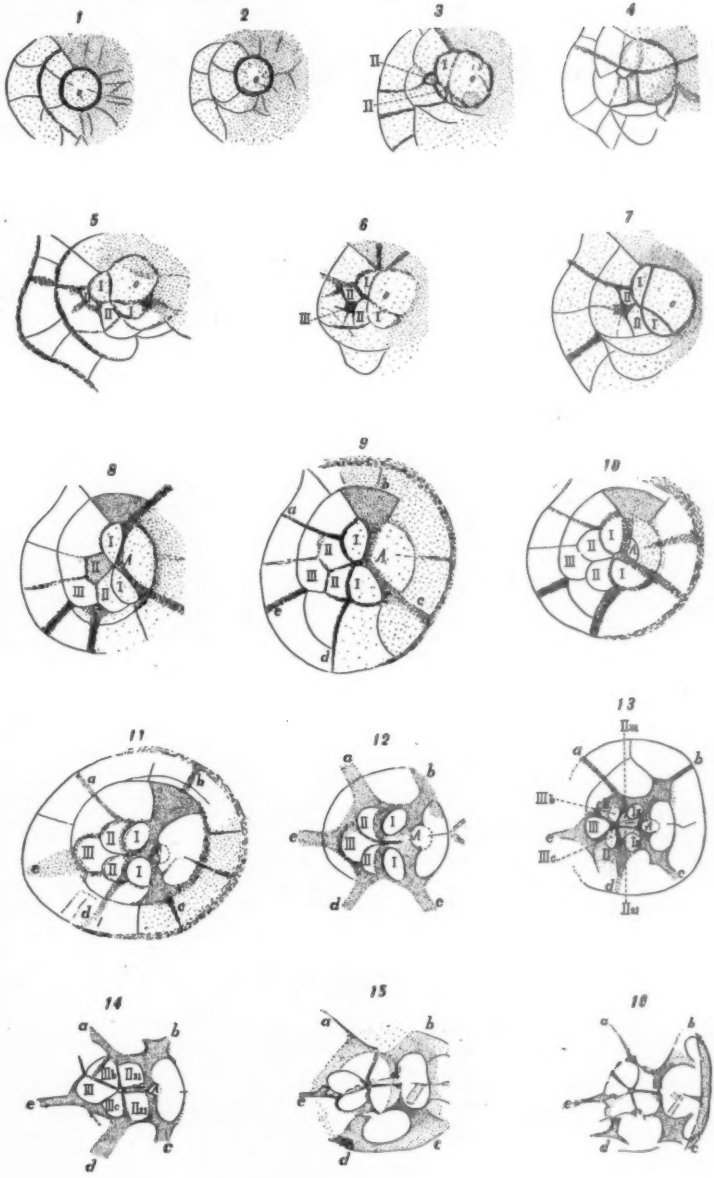
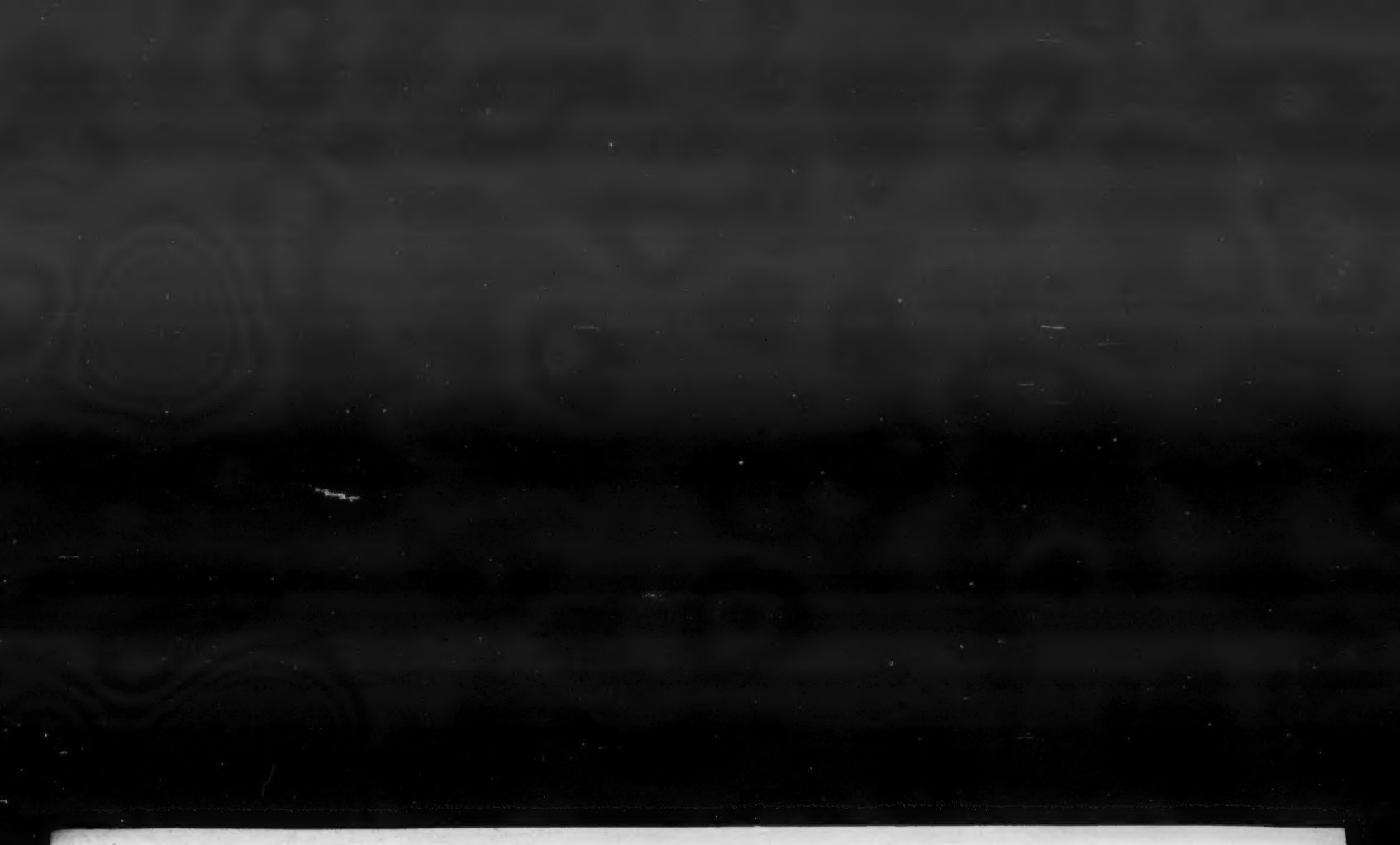
5. *A Magnetic Survey of Japan reduced to the Epoch 1895·0 and the Sea-level*, carried out by order of the Earthquake Investigation Committee. Reported by A. Tanakadate. 347 pp., 98 plates, Tokyo, 1904. The Journal of the College of Science, Imperial University of Tokyo, Japan, vol. xiv.—This large volume presents the results of the Magnetic Survey of Japan,

carried on, under the auspices of the Earthquake Investigation Committee, during the four summers from 1893 to 1896. The Appendix gives a complete list of the observations, reduced to 1895·0 and sea-level. A large number of plates and eleven beautifully executed maps accompany the text. Many of the maps are double, a thin rice-paper chart covering a second one on thick paper; in this way a double series of data are presented.

6. *Beiträge zur chemischen Physiologie*, herausgegeben von F. Hofmeister. Band VI. 1905. Braunschweig (F. Vieweg und Sohn).—The present volume, like its predecessors, contributes a large number of new data to the literature of physiological chemistry. Only a few of the 41 papers can be selected for special mention in this place. Many of them deal with the chemistry of metabolism. Thus von Bergmann and Langstein have investigated the "residual nitrogen" of the blood; Knop, the metabolism of aromatic fatty acids; Eppinger, the physiological formation of allantoïn and urea; Blumenthal, the assimilation limits for common sugars after intravenous introduction; and Steinitz and Weigert, the composition of the body after improper nutrition. Dr. von Fürth has published the details of an extensive study of the oxidative decomposition of proteids. Friedmann's research on the chemical structure of adrenalin, Pollak's paper on the diversity of trypsins, and Embden's various papers on carbohydrate metabolism indicate the scope of the journal. Students of haemolysis and related topics will be interested in the papers by Pascucci upon the chemistry of the stroma of the red blood corpuscles, and one by Hausmann on the behavior of saponin in the presence of cholesterin. L. B. M.

7. *Du Laboratoire à l'Usine;* par Louis Houllevigue, Professeur à l'Université de Caen, 299 pp., 12mo. Paris, 1904 (Armand Colin).—This useful little book discusses in elementary form a wide range of well-selected practical topics: the part played by machines; the gas meter; the transformation and distribution of energy; the industrial Alps; electro-chemistry; lighting by incandescence; the production and use of extreme cold; molecules, ions and corpuscles. The method of presentation is adapted to the requirements of the ordinary public interested in the applications of science.

8. *Traité Complet de la Fabrication des Bières;* par MM. G. Moreau and Lucien Lévy. 674 pp., 5 plates, 173 figures in the text. Paris, 1905 (Libr. Polytechnique, Ch. Béranger Éditeur, successeur de Baudry et Cie.).—This volume, like others which have preceded it from the same publishers and belonging to this series, is a very complete and exhaustive discussion of the subject of which it treats. This is somewhat out of the range of this Journal, but attention may be called to the discussion of the botanical side of the various forms of hops and barley, also of the yeast, and of the part played by bacteria; these have more than a technical interest. The illustrations are numerous and good and the whole presentation of the technical part of the subject is very thorough.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